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NS Live

AI needs you

Hear artificial intelligence expert Verity Harding discuss how lessons from three recent tech revolutions can empower us to shape the conversation around the future of AI. Tickets are now on sale for New Scientist Live, which will be held on 12 and 13 October at London's ExCeL Centre.

live.newscientist.com

Newsletter

Fix the planet

Earlier this month, one of the first real-world trials began of a form of geoengineering called marine cloud brightening. It is an attempt to make clouds more reflective, so that they bounce more of the sun's energy back into space. This week, we look at whether schemes like this can buy us time in the fight against climate change. Sign up to receive the free newsletter now.

newscientist.com/sign-up/fix-the-planet

Podcasts

Weekly

This week the team discuss why our ability to capture and store carbon in the ground – a technology relied upon in models of climate change impacts – has been massively overestimated. They also celebrate the world's largest computer based on the human brain and meet a musician who found tinnitus both disabling and inspiring. Plus, the songs birds dream about and a surprisingly enormous black hole in our cosmic backyard.

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Call of the wild See the majestic red deer in Italy's mountains

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Listen up A new understanding of hearing could mute tinnitus

Video

Strangely intelligent

Starfish, also known as sea stars, coordinate hundreds of tiny "feet" to hop about – and they do it without a central brain. Instead, each of their tiny appendages simply responds to changes in pressure. Studying this fascinating mode of unified movement may inspire future robots. You can watch a prototype bounce across a table on our YouTube channel.

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Tours

Rewilding in the central Apennines: Italy

Join Mario Cipollone from Rewilding Italy to see how ecosystems are being regenerated in the central Apennines. Wander in some of Europe's oldest beech forests tracking red deer and wild boar. This six-day tour starts on 23 September and costs £2795.

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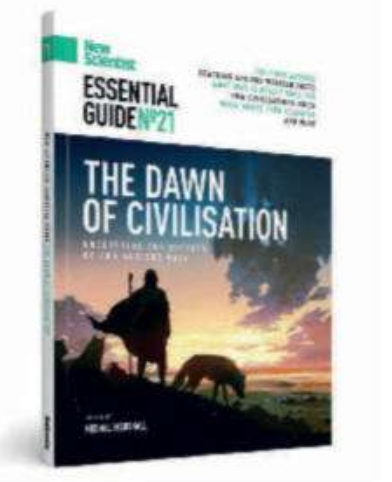
Newsletter

"Our chances of limiting global warming to 1.5°C are rapidly slipping away"



Essential guide

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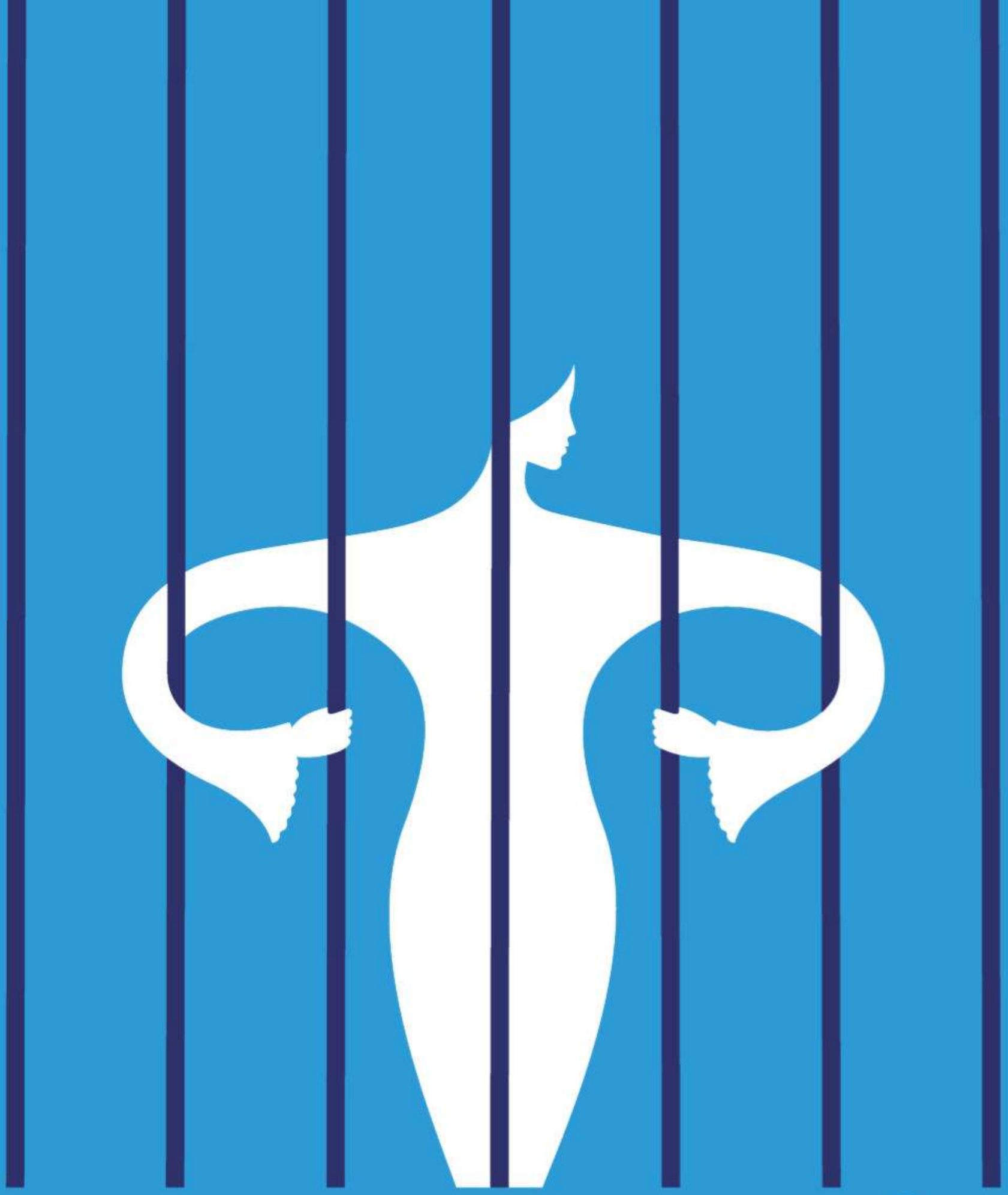

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Trash talk

It is too soon to write off innovative technologies that could end plastic waste

IN 1980, Disney World in Orlando, Florida, started work on a new way to generate power for the theme park, cutting its use of oil, the price of which had soared. The Solid Waste Energy Conversion Plant took trash, including plastic, and used a method called pyrolysis to turn it into combustible gases. It opened in 1982, but closed a year later, as the cost of running it mounted.

Today, environmental campaigners are invoking the Disney story to trash the reputation of a suite of new technologies, collectively known as advanced recycling, which take plastic waste and convert it back into brand new plastic.

Their argument is disingenuous. The failure of Disney's plant had more to do with a subsequent fall in oil prices than technological or environmental problems. Pyrolysis has improved a lot since the 1980s. And in any case, Disney's plant was designed to produce fuel, which isn't classed as advanced recycling.

As we report on page 36, advanced recycling is a rapidly innovating industry that could help to solve the global plastics crisis. It has the potential to take millions of tonnes of discarded plastic, most of which ends up in landfill, incinerators or the environment, and turn it back into a clean, fresh version by breaking it down to its molecular constituents. The goal is a circular economy where there is no longer any need to make "virgin" plastic from oil.

"Advanced recycling could turn millions of tonnes of used plastic into a clean, fresh version"

It isn't a panacea. There are issues around such plants generating toxic waste, their energy use and the perpetuation of conventional plastics ahead of newer, greener alternatives. Campaigners are right to argue that we would be better off phasing out plastics altogether. But practical considerations mean they aren't going away any time soon, and most advanced recycling technologies are better for the environment than the alternatives.

There is a serious discussion to be had around advanced recycling, not least whether it should be factored into a forthcoming global treaty on plastic pollution. Let's just make sure it is based on the facts, not Disney stories. ▮

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CONTACT US
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General & media enquiries
UK **Tel**+44 (0)203 615 6500
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US 600 Fifth Avenue, 7th Floor, NY 10020

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Materials science

A very unusual jewel blooms

This synthetic 3-carat diamond is the first in the world to be made exclusively from carbon taken from peony flowers. It was created by Chinese firm Luoyang Time Promise out of red flowers from the Luoyang National Peony Garden in China's Henan province. The stone is valued at 300,000 yuan (£33,000) and has been given to the peony garden.

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Humans

When did humans first travel north?

Evidence of human presence in Siberia 417,000 years ago indicates that hominins travelled north much earlier than we thought – and may even have reached North America, says **Michael Le Page**

EARLY humans lived at a site in Siberia that has been dated to 417,000 years ago, making it by far the most ancient early human site found this far north.

"This site dramatically revises our understanding of when humans reached high latitudes," John Jansen at the Czech Academy of Sciences told a press conference on 16 April. Other early human sites in the Arctic region are no more than 45,000 years old, he says.

The fact that early people had reached this far north means it is possible that they could have crossed the Bering Strait into what is now Alaska around this time, says Jansen. "It remains possible that people crossed into North America well before the earliest widely accepted timing."

An intriguing find

The site at Diring Yuriakh, near the city of Yakutsk in Russia, was found in 1982. It consists of primitive stone tools buried in layers of wind-blown sand. In 1997, it was shown that these layers were at least 260,000 years old, but their actual age remained unknown.

Now, Jansen and his colleagues have used a method called cosmogenic dating to date the layers to 417,000 years ago, plus or minus about 80,000 years. Jansen presented the team's preliminary findings at a European Geosciences Union meeting in Vienna, Austria, on 19 April.

The timing coincides with a warm interglacial period, he says, so it makes sense that people moved north at this time. "The age perfectly corresponds with the interglacial," says Jansen. Later glacial periods would have forced the people to move back south, he says.

No human remains have been found at the Siberian site, but based on the timing, it is likely that the inhabitants were *Homo erectus*, a species that evolved about 2 million years ago and spread from Africa to Eurasia.

Beyond this, nothing is known about them. We don't know if they used fire or made clothes, says Jansen, let alone if they had any specific adaptations to living so far north.

Although Diring Yuriakh is 2000 kilometres away from the Bering Strait, it is likely that some people lived closer to it, he says. If they hung on there during colder periods when the sea level was lower, they might have been able to reach North America.

"They would have been within striking distance of crossing the strait during low sea level," says Jansen. "And also, of course, there is the possibility of crossing sea ice."

This is just speculation, he says. The earliest evidence of humans in North America is from around 33,000 years ago.

OPENSTREETMAP CONTRIBUTORS

Could humans have crossed the Bering Strait between Russia and Alaska hundreds of thousands of years ago?

No genetic trace

If any early humans did make it to North America at this time, it seems that they went extinct before modern humans arrived, because there is no genetic trace of them within modern American peoples.

It is possible that some human DNA from this time remains frozen in Siberian permafrost, but the team can no longer visit the site because of Russia's invasion of Ukraine, says Jansen. The samples that were dated were taken in 2021, before the invasion.

"These are really interesting results," says Chris Stringer at the Natural History Museum in London.

"Given the warmth of this interglacial, it is certainly plausible that early humans were able to move even further north in places like Siberia, at least briefly," he says. "However, I think it is a speculation too far to suggest they could even have reached the Bering Strait and the Americas at this time."

During this interglacial, sea level was several metres higher than today, says Stringer, which would have made reaching the Americas even more difficult.

Earlier this year, Jansen and his colleagues dated another early site, in Ukraine, to 1.4 million years ago. ▮

417,000
Number of years ago that early humans were in Siberia

45,000
Age in years of other early human sites in the Arctic region

33,000
Number of years ago that humans reached North America, according to current evidence

VASILIJ LYTKIN

The archaeological site at Diring Yuriakh, Russia

Astrophysics

Knot theory could help spacecraft shift to new orbits for free

Leah Crane

WHEN a spacecraft is circling a planet or sailing between moons, navigating between different orbits can be tough – but a trick from knot theory may help. It can be used to identify points called heteroclinic connections, where a craft can transfer from one orbit to another without burning its precious fuel.

"These heteroclinic connections, a lot of the time we know there are some for a pair of orbits, but there's not a good way to know exactly how many," says Danny Owen at the University of Surrey, UK. "It's just a case of getting lots of data and hoping for the best." This requires either huge amounts of computer power or a "guess-and-check" method.

Owen and Nicola Baresi, also at the University of Surrey, came up with a way to find all of the heteroclinic connections for any pair of orbits. In knot theory, the number of times two lines cross is denoted by a figure called the linking number. The researchers realised that the linking number of a pair of orbits should be equal to the number of heteroclinic connections. Any time two gravitationally stable orbits cross, that is an opportunity for a spacecraft to transfer between them.

By representing each orbit as a series of closed loops, like rubber bands, the researchers could find the linking number and spot each heteroclinic connection (*Astrodynamics*, doi.org/msjb). "If you plot two lines in 3D space, chances are that they're not going to intersect because they're infinitesimally narrow," says Owen. "So you run these simulations of closed loops, and if the linking number changes, you know that they have passed through each other."

Any spot where the linking number changes is a place where a spacecraft could pass from one orbit to the other without firing its thrusters or using any fuel. ▮

Genetics

Your DNA seems to influence how much you like listening to music

Roberta Angheleanu

DAWN FLETCHER-PARK/SOPA IMAGES/LIGHTROCKET VIA GETTY IMAGES

Die-hard fans at festivals like Copenhell, Denmark, may have an innate love of a tune

HOW much we enjoy music may partly come down to our genetic make-up, according to a study of thousands of twins.

The pleasure people get from a tune has been linked to its effects on our emotional responses, alertness and ability to form social connections. The degree of enjoyment differs from person to person, but little is known about why.

To investigate the role of genetics, Giacomo Bignardi at the Max Planck Institute for Psycholinguistics in the Netherlands and his colleagues looked at more than 9000 twins from the Swedish Twin Registry, a medical research resource. About 3400 were identical and 5600 non-identical.

The former share the same genome, while non-identical twins share only half their genomes, as is also the case with any non-twin biological siblings. All the twins in the study, who were between 37 and 64 years old, were raised in the same households and so had similar environmental exposures while growing up.

This made it easier to tease out genetic contributions.

The researchers first got the twins to complete the Barcelona Music Reward Questionnaire, which assessed how much pleasure they get from music. For example, they were asked the extent to which they agree with statements such as "when I share music with someone I feel a special connection with that person" and "in my free time I hardly listen to music".

"The apparent influence genetics has on enjoying music isn't necessarily linked to musical talent"

The team then used a statistical method to analyse the relative contributions of genetics and environmental factors to the degree of musical enjoyment among the twins. This showed that genetics seems to play a substantial role in influencing how much pleasure music brings, with the identical twins being more than twice as similar in this trait than the non-identical ones.

In another part of the experiment, Bignardi and his team tested the participants' abilities to distinguish between different melodies, rhythms and pitches, with previous research having linked genetics to musical ability. They found that the apparent influence genetics has on enjoying music isn't necessarily linked to musical talent (bioRxiv, doi.org/msh4).

The study is provocative, says Peter Harrison at the University of Cambridge. "It's intuitive that musical ability might have a genetic basis; it provides an easy explanation for why some people seem to possess an innate 'knack' for music that enables them to develop prodigious skills from a young age." It is perhaps less obvious that the degree of pleasure from listening to music is influenced by genes, so it is interesting the study finds this effect, he says.

The results add a new piece to the puzzle of why music can have such a powerful effect on certain people and "open up new possibilities for using inter-individual differences to gain insights into the biology of a key aspect of human behaviour", the researchers write in their paper.

Yet the role of cultural influences in music enjoyment shouldn't be understated, says Nick Collins at Durham University, UK. "There could be an underlying genetic component to certain auditory capabilities and preferences, but there is a heavy cultural component to music evolution that is not addressed by genetics alone." ▮

Developmental biology

Groups of single-celled creatures could explain how embryos evolved

Claire Ainsworth

A SINGLE-celled creature originally found in shallow sea sediments around Hawaii develops into multicellular structures with remarkable similarities to animal embryos. The finding could help us understand more about how and when embryonic development evolved.

One of the biggest questions in biology is how a single cell, the fertilised egg, coordinates its development into a complex multicellular body with many different cell types all doing the right things in the right places. We have learned a great deal about it, but how the process evolved from our single-celled ancestors remains mysterious.

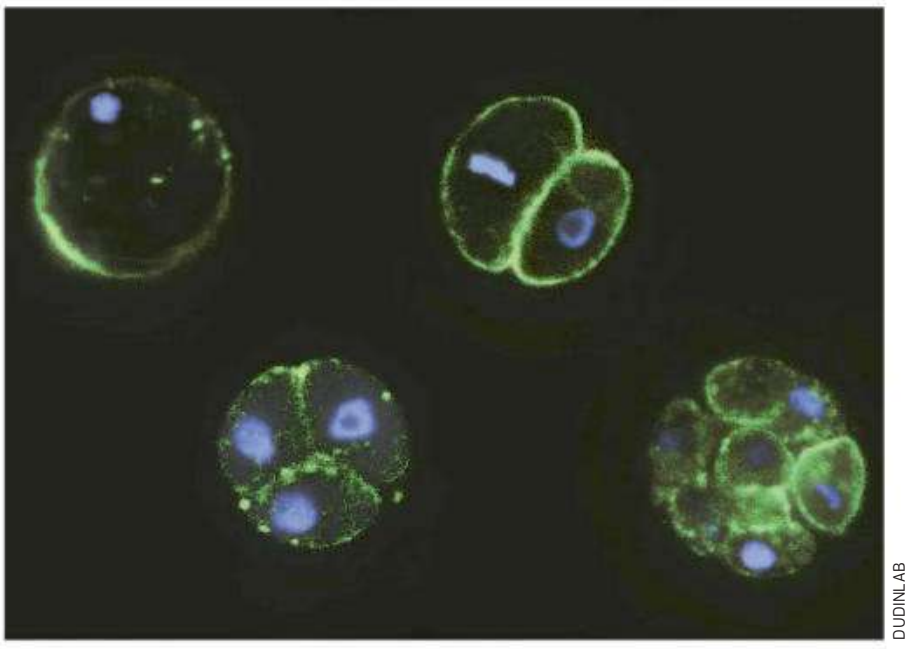
Clues have come from our modern single-celled relatives, many of which go through a brief multicellular stage as part of their life cycle. Our closest single-celled relatives, the choanoflagellates, for example, divide to form small colonies. Unlike animal embryos, however, they do this in response to environmental

"There are more ways to assemble the 'building blocks' of multicellularity than we thought"

change and don't seem to have a program coordinating how different cell types develop.

Recently, researchers have looked at more distant relatives, such as the ichthyosporeans, whose ancestors branched off from the lineage that gave rise to animals about a billion years ago. They have a multicellular stage of their life cycle that arises independently of any environmental cue.

To find out more, Omaya Dudin at the Swiss Federal Institute of Technology in Lausanne and his team studied an ichthyosporean species called *Chromosphaera perkinsii*. The team found that once single *C. perkinsii* cells reach a fixed diameter, they divide without growing in size (pictured), just as animal embryos do in the first stages of development.



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***Chromosphaera perkinsii* development is akin to early embryo growth**

The cells remain in this cluster, which can be hundreds of cells, for about a third of their life cycle and form at least two different cell types (bioRxiv, doi.org/mr4f). "That was the biggest surprise," says Dudin.

What's more, the way in which the cells divide and the three-dimensional structures the colonies adopt are remarkably similar to animal embryos in the earliest stages of development. Studies of gene activity in the colonies revealed parallels with that seen in early-stage animal embryos.

All of this suggests that genetic programs for guiding complex multicellular development were either present at least a billion years ago, long before the evolution of animals, or evolved independently in ichthyosporeans, says Dudin.

The findings could also help to resolve a long-standing debate about some 600-million-year-old embryo-like fossils that some scientists have used to argue for a more ancient evolutionary origin of animals. The new findings raise the possibility that they were instead colonies of ichthyosporean-like organisms.

The apparent degree of different cell type development in *C. perkinsii* colonies is "truly novel and striking", although it isn't clear to what extent they cooperate with each other, says Thibaut Brunet at the Pasteur Institute in Paris.

The findings are adding to a growing body of evidence challenging our notions of multicellularity and showing that there is more diversity and versatility than we thought existed even a few years ago, he says. "There are many more ways to assemble the 'building blocks' of multicellularity than we previously thought." ▮

Physiology

Cocaine may hijack the way the brain prioritises food

Tom Leslie

PERSISTENT use of drugs such as cocaine and morphine is thought to affect the way the brain prioritises the body's basic needs – and we are now starting to understand how.

When people frequently take these drugs, they might see changes in their behaviour that lead them to choose to take drugs instead of doing essential things like eating and drinking.

A brain pathway called the mesolimbic reward system is thought to be involved in this. Now, Bowen Tan at Rockefeller University in New York and his team have used microscopy to track the activity of individual neurons in mice going through withdrawal after repeated exposure to cocaine or morphine.

"The field has long been debating whether there is a specialised cell type that encodes drug value only and a specialised cell type that encodes natural reward value only," says Tan. "What we saw is that these drugs of abuse commonly activate the same set of neurons as the natural rewards."

The researchers also observed that the neural response to satisfying basic needs became disorganised after the mice were given cocaine or morphine, which occurred alongside a decreased consumption of food and water (*Science*, doi.org/mr4h).

"Strong neural responses to food or water almost become displaced by responses to drugs," says Jeremy Day at the University of Alabama at Birmingham. This suggests that drug rewards can override how the brain translates need into behaviour to satisfy the need, he says.

Tan and his team also identified a gene, called *Rheb*, that seems to be necessary for drugs to have this effect. *Rheb* is part of a cell-signalling pathway that is also found in people, so inhibiting this pathway could be used as a therapy for substance misuse, he says. ▮

Environment

Narrow window for geoengineering

Shading the planet might stop the West Antarctic ice sheet melting, but only if done soon

Michael Le Page

USING aerosols to shade Earth's surface from sunlight could postpone or even avoid the collapse of the West Antarctic ice sheet – but only if we start soon and also make big emissions cuts, according to computer modelling studies by two independent teams.

"There's a time window that we can do this, and if we dither, there's just no point in doing it," says John Moore at the University of Lapland in Finland, who led one of the teams. "And that time window I think is a hell of a lot closer to 25 years than it is to 100 years."

"The study we did says 2030 at the latest," says Johannes Sutter at the Alfred Wegener Institute in Bremerhaven, Germany, who was part of the other team.

However, neither is suggesting we rush to start geoengineering, because there are many unknowns.

The West Antarctic ice sheet is known to be vulnerable to collapse because it rests on the seabed rather than land above sea level, meaning it can be melted from below by relatively warm water. What's more, this seabed becomes deeper further back, meaning once the ice sheet begins to retreat, a larger area of ice will be exposed to the warm water and the melting will accelerate.

Previous studies suggest we are approaching the tipping point beyond which the collapse of the West Antarctic ice sheet becomes inevitable, which will add more than 3 metres to the already-rising global sea level. "We're in this terrible situation where we're walking along this cliff edge," says Moore. "We know that we are very, very close to it."

The West Antarctic ice sheet could raise sea levels by over 3 metres if it melts

MARIO TAMA/GETTY IMAGES

To find out if we can avoid this collapse, Moore, Sutter and their colleagues used computer models to explore the effects of using aeroplanes to spread sulphate aerosols that would reflect sunlight back into space.

Sutter and his team fed the output from a global climate model run until 2300 into a model of the Antarctic ice sheet. They found that avoiding ice sheet collapse required either drastic emissions cuts or geoengineering to begin almost immediately, and even then geoengineering worked only in conjunction with large emissions reductions.

"But it's way too early to make conclusive statements," says Sutter. Different climate models will produce somewhat different results, he says.

Moore's team didn't use an ice sheet model, but did use six different global climate models, run until 2100. The researchers found that adding sulphate to the atmosphere speeds up the winds that circle the pole, keeping warming waters away from the edge of the ice sheet.

Sutter and Moore presented their findings at a meeting of the European Geosciences Union in Vienna, Austria, on 18 April.

"I think we're pretty much in agreement, it's just that [Sutter is] using different models," says Moore. "We absolutely do agree that the earlier you do something, the better the chance of it actually working."

What is also clear is that once we pass this tipping point, the only way to make the ice sheet regrow would be to cool the planet down to the temperature it was during the last glacial period, says Sutter. "No one wants that." But with the world failing to cut emissions, the chance of avoiding the collapse of the ice sheet seems low, he says.

More research on the West Antarctic ice sheet and the effects of geoengineering is urgently needed so that political leaders can make an informed judgement on whether we should resort to using the technique, says Moore. ▮

Forensic science

Drug residue can be detected in fingerprints

FORENSIC scientists have developed a technique to detect signs of drugs on fingerprints from crime scenes.

"That information, the presence of drug particles, is an almost untapped resource," says James Reynolds at Loughborough University, UK. That is because investigators use thin gelatine layers, called gel lifters, to lift fingerprints. These introduce chemicals to samples, making it difficult to identify trace amounts of drugs or explosives on them.

Reynolds and his colleagues used a technique called mass spectrometry to identify chemical compounds from gel-lifted fingerprints. First, they created fingerprints by placing their hands inside plastic gloves. They then put on the gloves inside out and handled small amounts of zolpidem, a common date-rape drug. This was to prevent their skin from absorbing the sedative. They gently brushed off the excess from a contaminated glove finger before pressing it on glass, metal or plastic surfaces. They repeated this procedure 10 times with and without zolpidem for each surface.

After gel-lifting the prints they left, the researchers extracted chemicals from them with a drop of liquid and placed the droplet in a machine that used high-voltage electricity to suspend the particles inside in the air. This allowed them to identify zolpidem with 100 per cent accuracy for the first eight consecutive fingerprint touches (*Drug Testing and Analysis*, doi.org/msk2).

"Where it's got real potential is to see if somebody had been handling a drug"

"Our method allows us to detect all that information from these forensic gel lifts, which no one's done before," says Reynolds. "Where it's got real potential is to see if somebody had been handling a drug, especially in cases where they administered it to somebody to render them easy to assault."

It would also be helpful if the technique could detect drug metabolites, or molecules present in people's sweat when they use drugs, says Ralph Ristenbatt at the Pennsylvania State University. ▮

Grace Wade

Physics

Single atoms caught becoming waves

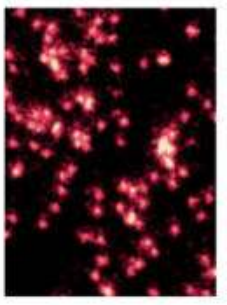
Quantum mechanics predicts a strange dual identity for particles, and now we have seen it in action

Karmela Padavic-Callaghan

ATOMS have been clearly imaged behaving like waves, as predicted by quantum mechanics. Such images could be used to study this exotic and poorly understood quantum behaviour.

The fact that particles like atoms can behave like waves is a key insight of quantum theory. One specific shape of wave that an atom can adopt is known as a "wave packet", which is like a series of ripples on water, but more bunched up and compressed.

Physicists can predict how a wave packet will change over time by using an equation developed by physicist Erwin Schrödinger. This makes analysing wave packets a great test for how well an atom can be controlled and imaged in the quantum realm, says Tarik Yefsah at the French National Centre for Scientific Research and the École Normale Supérieure in Paris.



JORIS VERSTRATEN, ET. AL

Atoms behaving like particles appear as a red dot, but spread into a wide blob when they act like a wave

He and his colleagues have chilled lithium atoms to close to absolute zero so they display quantum properties. To do this, the team placed the atoms in a small, airless chamber, then hit them with lasers and magnetic fields, which lowered their energy and made them cooler.

The team used the same tools to control the atoms' quantum states and their shape as waves. Consequently, the researchers arranged the atoms so as not to be too close to each other, made sure each atom's quantum state corresponded to a wave packet and then loosened some of the forces that were keeping the atoms pinned in place so they could watch the wave packets change.

In images, each atom started as a tight dot. The Schrödinger equation predicts that a wave packet that is free to move rather than being held still will spread as time goes on – that is, the dot should become larger and fuzzier. The images the researchers took of the lithium atoms showed exactly that (see image, above left). Yefsah says the team could also show how altering the initial properties of the wave packet, such as its width, changed the way it spread. In all cases, the atoms' behaviour in the images agreed with Schrödinger's equation (arXiv, doi.org/mskf).

Peter Schauss at the University of Virginia says the findings show the high degree of control the researchers had over the processes used to cool and image the atoms.

He says that atoms of this type, which are called fermions, are very interesting to physicists, especially when they interact with each other. For instance, theorists think that strongly interacting ultracold fermions could form many new quantum phases of matter – but the mathematics is too difficult to predict exactly how and experiments could add clarity, says Schauss.

Yefsah and his colleagues are hoping to use the procedure on systems of strongly interacting atoms next. Images of them could reveal quantum wave behaviour similar to those in the exotic quantum matter inside dense neutron stars, or in the "soup" of highly interacting particles that existed right after the big bang, says Yefsah. ▮

Archaeology

Ancient Maya burned dead rulers to mark new dynasty

ABOUT 1200 years ago in a Maya city, the bones of several royal people were burned and unceremoniously discarded within the foundations of a new temple. These recently discovered remains may have marked a fiery political transition at a time of upheaval in the Maya world.

Christina Halperin at the University of Montreal and her colleagues discovered the remains in 2022 at the archaeological site of Ucanal in Guatemala.

The researchers found the haul mixed in with rocks beneath a pyramid temple structure. The deposit contained the bones of at least four people, along with thousands of ornamental fragments and beads. The bones of two individuals and many of the ornaments showed evidence of burning at high temperature.

DR CHRISTINA T. HALPERIN

A pendant found with the burned remains of royal people at a Maya temple

It was clear this wasn't a normal set of remains, says Halperin. But it was the nosepiece and obsidian eye discs of a burial mask that showed they were royal individuals.

Despite their apparent highborn origins, the royals' burned remains weren't carefully buried – they were instead "dumped there", says Halperin. Radiocarbon dating of the bones and ash also indicated at least one individual had died up to a century before the remains were burned between AD 773 and 881. This suggests the bones were exhumed from a previous burial and burned (*Antiquity*, doi.org/mr4g).

This timing corresponds with the rise of a new leader at Ucanal named Papmalil, an outsider who came to power amid a wider unravelling of Maya society. The researchers think the deposit may be the product of a "fire-entering rite", a Maya ritual that marked the destruction and end of the previous dynasty and the preeminence of the next. "This rite seems to be both an act of veneration, but also an act of destruction," says Halperin. ▮

James Dinneen

Health

Skin-deep wounds can affect gut health

Sneha Khedkar

THE effects of skin injuries can penetrate all the way to the gut, according to experiments in mice.

We know there is a connection between the health of our skin and inner organs – people with conditions such as psoriasis often have gut-related issues like food allergies, and they carry different intestinal microbes than people without the skin conditions.

It has often been assumed that the gut influences the skin, says Richard Gallo at the University of California, San Diego. To see if it can work the other way round, Gallo and his colleagues cut 1.5-centimetre incisions in the skin of some mice and left others unharmed. They then isolated and sequenced germs from the rodents' faeces.

The two groups had different microbes in their guts – wounded mice had fewer beneficial ones, such as *Bacillus clausii*, and more disease-causing bacteria, including *Enterorhabdus caecimuris*.

Similar results were seen when the researchers tweaked mouse genes to release an enzyme that breaks down the molecule hyaluronan, which maintains the skin's water content. The researchers think this substance could contribute to the "skin-gut axis" if a skin injury releases fragments of hyaluronan, which can trigger an immune response in the gut.

Further experiments showed that mice with skin wounds or damaged hyaluronan were more susceptible to the digestive disorder colitis than the control mice (*Nature Communications*, doi.org/mr48).

Larry Dishaw at the University of South Florida says cortisol – a hormone released after stress that can affect the microbiome – could play a role.

Gallo hopes the finding can lead to therapies for controlling skin conditions to improve gut health in humans. ▮

Marine biology

Extreme heat in 2023 linked to slump in growth of marine life

Madeleine Cuff

PAUL KENNEDY/ALAMY

High temperatures can hinder the growth of algae for fish to eat

RECORD sea temperatures in 2023 may have triggered an unprecedented global decline in the growth of phytoplankton and algae, which form the base of the marine food web.

Last year, swathes of the world's oceans were gripped by extreme marine heatwaves, caused by climate change and a transition to hotter El Niño conditions in the Pacific Ocean.

On average, on any one day in 2023, nearly a third of the global ocean was experiencing a marine heatwave, the World Meteorological Organization reported last month.

The spikes in sea surface temperatures sparked a slump in the production rate of phytoplankton, algae and bacteria that sustain ocean ecosystems, known as net primary productivity (NPP), a new study suggests.

Marshall Bowles at Louisiana Universities Marine Consortium and his colleagues used 21 years of satellite data measuring the colour of the sea surface, which is affected by the amount of green pigment in photosynthesising organisms, to estimate the rate of NPP in the world's oceans.

In April 2023, when global sea surface temperatures were at record levels, NPP dropped by 22 per cent compared with the 21-year average.

22%

Drop during 2023 in organisms that sustain ocean ecosystems

Equatorial regions of the Atlantic and Pacific, as well as the northern Atlantic, saw the largest falls in productivity rates, the study found. Those regions also saw some of the most severe marine heatwaves – in parts of the North Atlantic, water temperatures were 4°C above normal in June 2023.

NPP rates remained lower than normal throughout the northern hemisphere summer, according to the study. The global average sea surface temperature peaked in August 2023, and in September the global rate of NPP was almost 16 per cent lower than the 21-year average. The study only considered data up to September 2023, but global sea surface temperatures have remained well above 2023 levels so far in 2024.

Increased ocean temperatures don't always lead to a reduction in NPP, says Zoe Jacobs at the UK's National Oceanography Centre. "In tropical regions, if you have a marine heatwave the productivity is generally going to be less. But if it's occurring in the polar regions, it might well be increased," she says.

Marine ecosystems can usually recover from "blips" in productivity, adds Jacobs, so 2023's extreme weather may not cause lasting damage. But she says the findings are "very concerning" given the increased frequency of extreme heat events occurring under climate change.

If a decrease in NPP were sustained, says Mark Moore at the University of Southampton, UK, it may cause wider marine ecosystem disruption. However, he says more research is needed before we can blame water temperatures alone for a drop in the NPP rate. ▮

Zoology

Nocturnal ants use polarised moonlight to find their way

James Woodford

THEY may have poor eyesight, but bull ants can navigate at night using even the faintest polarised light from a crescent moon.

Light from the sun and the moon consists of waves that vibrate in different directions, but on entering the atmosphere it becomes polarised, and the waves align in the same direction across the sky. Many animals can detect this polarity in sunlight and use it to get a sense of direction, even if they can't see the sun directly.

The bull ant *Myrmecia midas*, which is native to Australia, is the first animal known to use the polarity of moonlight for navigation, says Cody Freas at Macquarie University in Sydney.

These ants emerge from their nests after sunset to forage for food in trees and then return home in the dawn twilight.

DR. AJAY NARENDRA

Myrmecia midas is a species of bull ant that emerges from its nest after sunset to forage for food in trees

To test how the ants navigate, Freas and his colleagues placed a polarising filter above them as they returned to their nests and rotated it. The filter altered the polarisation patterns of the moonlight and made the ants change direction in predictable ways. When the filter was removed, the ants changed their course back to the correct route (bioRxiv, doi.org/msjm).

Shrubs and trees often block a direct view of light for the ants, says Freas. "But they have still got patches in the canopy where the sky is clear and this polarising pattern makes its way through to the ants. That is enough for them to keep their celestial compass working." ▮

Technology

Ships smuggling Russian oil spotted in satellite images by AI

Jeremy Hsu

ARTIFICIAL intelligence can detect stealthy cargo transfers between "dark ships", vessels that have switched off their identification transponders. This could make it easier to track ships secretly transferring crude oil in defiance of international sanctions.

Such ship-to-ship transfers have skyrocketed since Russia's invasion of Ukraine spurred the European Union to restrict imports of Russian crude oil. Although the G7 countries and allies allow member countries' ship operators and insurance services to transport some Russian oil, they have capped the maximum price to reduce profits for Russia.

"Under normal prewar circumstances, there were very few dark ship-to-ship transfers," says Ollie Ballinger at University College London. But the sanctions and price caps have led to more oil smuggling, and Ballinger used AI to prove it. His AI-powered search of satellite images revealed more than 400 dark ship-to-ship transfers that took place in the Kerch Strait near Ukraine and Russia between 2022 and September 2023 (arXiv, doi.org/msn9).

GALLO IMAGES/COPERNICUS SENTINEL 2018/ORBITAL HORIZON/GETTY IMAGES

The Kerch Strait connects the Sea of Azov and the Black Sea

400+

Number of "dark" ship transfers spotted in the Kerch Strait

He started by finding legitimate ship-to-ship transfers in the Kerch Strait. To do so, he used public Automatic Identification System (AIS) data, which ships on the move or at anchor are supposed to broadcast constantly. AIS data includes vessel identification, GPS coordinates and additional information about the ship dimensions and type. Ballinger deployed an algorithm that used this information to find any two identifiable ships that spent more than 2 hours within 500 metres of each other without actively moving, then flag them as examples of ship-to-ship transfers.

Then, he collected daily high-resolution satellite images of the Kerch Strait captured by the Earth-imaging company Planet. By combining known locations and timings of ship-to-ship transfers with the matching satellite imagery, he created a data set to train an AI program based on the publicly available YOLO object detection model.

The fully trained AI can spot ship-to-ship transfers solely from scrutinising satellite imagery, even if one or both partners are dark ships that don't broadcast AIS data. It can identify four types of ships – including smaller general cargo or bulk carrier ships and large or very large oil tankers – and transfers involving either dry cargo or liquids like fuels.

It can search the equivalent of 115 square kilometres per second while finding the most relevant results 97 per cent of the time. As one example, Ballinger used this method to track possible transfers between a known Russian oil tanker named the Vladimir Monomakh and various dark ships.

The method could help track down the owners of ships in the shadowy fleet of primarily older vessels sailing without standard Western-backed insurance, says Elisabeth Braw at the Atlantic Council, a think tank in Washington DC. More than 1400 such dark ships are regularly moving cargo to and from sanctioned countries such as Russia, Iran and North Korea, according to UK-based analytics company Windward.

A lot of manual work is needed to identify dark ships, says Braw. "If AI can help us detect them and detect their movements, all the better." ▮

Is Amazon's robotic lab a vision of the automated future?

The online retailing giant says robots will work alongside humans, but fears over job losses persist, says **Alex Wilkins**

THE world's largest manufacturer of robots is a company you have probably heard of. As of last year, Amazon had installed more than 750,000 robots in its warehouses, and it is investing hundreds of millions of pounds on developing and building more. Many of these robots perform tasks that were once carried out by people, such as packing, sorting and labelling. Are we seeing the beginning of a new wave of automation replacing human workers across many industries?

To find out, I visited Amazon's Operations Innovation Lab, where it develops and tests new robots. Located a stone's throw from the Italian Alps in the town of Vercelli, the robotic lab was opening to the press and the public for the first time in an effort to assuage fears about job losses.

I had seen some of the robots that make up Amazon's packaging line in videos, but seeing their speed and complexity up close was astounding. Snaking around a vast warehouse set up like an exhibition space, they were twisting and writhing in constant motion.

Rubber suction cups guided by computer vision AI placed packages on conveyor belts, while a robotic arm the size of a double-decker bus fastened boxes onto pallets. Occupying a central location was Amazon's shiny new robot it calls the Universal Robotic Labeller (URL), a spider-like device that can print and stick a label to any package, regardless of shape or size.

Stefano La Rovere, Amazon's director of global robotics, says that the URL will mean warehouse workers will no longer have to perform the repetitive motions of fixing labels to unusually shaped packages, freeing them up to work on other tasks like operating or maintaining the URL machine.

"The important thing is that every time we develop the technology, we also create a new training package for the employees to learn new skills," says La Rovere.

But it is unclear whether creating new jobs and retraining staff can happen quickly enough to prevent job losses, says Carl-Benedikt Frey at the University of Oxford. While new jobs, like robot technicians and software engineers, were created when roles in the manufacturing industry were automated away, there is no guarantee that this will happen at a sufficient pace in the future, he says. "There is no law of economics that suggests that those employment opportunities must counterbalance those jobs that are being displaced," says Frey.

I heard from multiple Amazon employees at the event that the goal is for the machines to work alongside humans. According to La Rovere, more than "50,000 jobs have been enhanced by the use of robotics and technology", though he didn't go into specifics.

£600m

Amazon's investment in robotic equipment in Europe over 5 years

Amazon has over 1.5 million full-time and part-time employees, many of whom carry out tasks I saw being performed by robots. If its £600 million investment in robotic equipment isn't going to put some people out of work, it will need a vast programme of retraining and legions of new jobs.

"Automation is good, but it's an illusion to think that automation automatically means more employment opportunities and more interesting work for the people affected by it," says Frey. "That has certainly not been the historical experience."

Amazon's vision of a human-robot love-in is also hard to square with the company's recent testing of humanoid robots in its warehouses. Last year, it began testing the Digit robot, created by firm Agility Robotics, in one of its Seattle warehouses. When I asked Sarah Rhoads, who oversees Amazon's global workplace safety, what role these robots might play in the near future, she said that they were "so new and emerging it's too early to speculate on".

Even if Amazon doesn't place humanoid robots at the centre of its automated vision, there is huge interest in them, not least from ex-Amazon CEO Jeff Bezos. Bezos has invested $100 million in Figure AI, a company with the stated goal of bringing "a general purpose humanoid to life".

Last week, robotics company Boston Dynamics also unveiled its sleek and nimble fully electric Atlas robot, a replacement for the previous hydraulic model. The company says it is "designed for real-world applications", and will be first tested in Hyundai's car factories.

The extent to which robotic technology will affect human jobs is highly uncertain, says Leslie Willcocks at the London School of Economics, and it will take time for full automation to take place. However, recent studies have estimated that repetitive, low-skilled work, as well as data collection and data processing tasks, will fall by 12 per cent as a share of all work by 2030 due to automation, he says. ▮

Alex Wilkins's trip was paid for by Amazon

SAM TODD/AMAZON

Inside Amazon's Operations Innovation Lab in Vercelli, Italy

Briefing

What caused the floods in Dubai?

Cloud seeding almost certainly didn't play a big role in the flooding on the Arabian peninsula, but the heavy rains may have been exacerbated by climate change, says **James Dinneen**

RECORD rainfall hit the Arabian peninsula last week, causing flooding in Dubai and Abu Dhabi, as well as other coastal cities in the United Arab Emirates.

Some parts of the UAE received 25 centimetres of rain in 24 hours and the subsequent floods closed schools and grounded flights. The extreme weather prompted speculation on social media about whether the UAE's long-standing cloud-seeding programme played a role. Here is everything you need to know about the situation.

How unusual was the recent rain in the Arabian peninsula?

In the UAE, it was the most extreme such event since records began in 1949, according to the state-run Emirates News Agency. Between 15 and 16 April, several parts of the country saw more rain in 24 hours than normally falls in an entire year. Heavy rains are unusual for the desert region, although not unheard of – the UAE saw heavy rain and flooding in 2016, for instance.

Drainage systems in the UAE's coastal cities were overwhelmed by runoff, which led to flooding. Dramatic images of planes taxiing through standing water at the Dubai International Airport were shared widely online.

In the neighbouring country of Oman, flash floods killed at least 18 people. Bahrain, Qatar and part of Saudi Arabia also saw unusually heavy rain.

What is cloud seeding and did it play a role in the extreme rain?

Cloud seeding is a method of increasing precipitation that has been around since the 1940s. It involves spraying a powder, such as silver iodide, into clouds from planes or rockets, or by burning it from ground-based stations. Droplets of supercooled water can form around these particles, which then fall to the ground as rain or snow.

The UAE has maintained one of the world's most extensive cloud-seeding programmes since 2002. In an effort to increase freshwater resources in the arid region, planes regularly fly cloud-seeding missions.

Speculation that cloud seeding may have played a role in the recent rain was fuelled after a meteorologist from the UAE's National Centre of Meteorology (NCM) told Bloomberg News that planes had seeded clouds above the country in the days before the storm. However, the NCM later said in a statement that no seeding had taken place during the storm.

"We take the safety of our people, pilots and aircraft very seriously," it said. "NCM doesn't conduct cloud seeding operations during extreme weather events."

Heavy rain last week caused floods in Dubai in the United Arab Emirates

REUTERS/AMR ALFIKY

Even if cloud seeding had taken place during the storm, it would have had at most only a marginal effect on the amount of precipitation, and only in local areas. The extent of the rain across several countries, and the limited impact of cloud seeding in general, suggests it almost certainly played no significant role. "There is no technology in existence that can create or even severely modify this kind of rainfall event," said Maarten Ambaum at the University of Reading in the UK in a statement.

He pointed out that cloud seeding would have little effect on clouds that forecasts had already predicted would dump rain on the region. And that is assuming cloud seeding is effective at all.

"Many of the claims of successful cloud seeding are wrong, scientifically flawed or actual fraud," says Andrew Dessler at Texas A&M University. "This makes most atmospheric scientists very sceptical of cloud seeding."

What meteorological factors were behind the rain?

The extreme precipitation that hit the Arabian peninsula was driven by a large storm called a mesoscale convective system. Suzanne Gray at the University of Reading says this occurs "when lots of individual thunderstorms amalgamate to form a single, large, high-level cloud shield".

Forecasters were projecting a high risk of flooding in the region at least a week ahead of the storm. Writing on X, Jeff Berardelli, a meteorologist at WFLA-TV in Florida, linked the storm to a blocking pattern created by a slow moving jet stream.

Did climate change worsen the rain?

Connecting this specific event to climate change would require more analysis, but it probably played a role in increasing the rain's intensity.

"These types of intense rainfall events can be made more extreme due to climate change, as a warmer atmosphere will hold more water vapour," says Ambaum. Changing temperature may also affect patterns of atmospheric circulation in ways that change precipitation.

For instance, a recent study found that the same type of storm as the one that drove this extreme rain event has occurred 95 times in the region since 2000, and is most common over the Arabian peninsula in March and April. But it also found an increase in the duration of such storm events since 2000 over the UAE, which may be linked to warming temperatures.

Another climate modelling study projected a 10 to 25 per cent increase in the UAE's annual precipitation by the middle of the century, characterised by more heavy precipitation events. ▮

Mathematics

Particles create hypnotic patterns

If a particle never retraces its steps, its trail can create stunning images

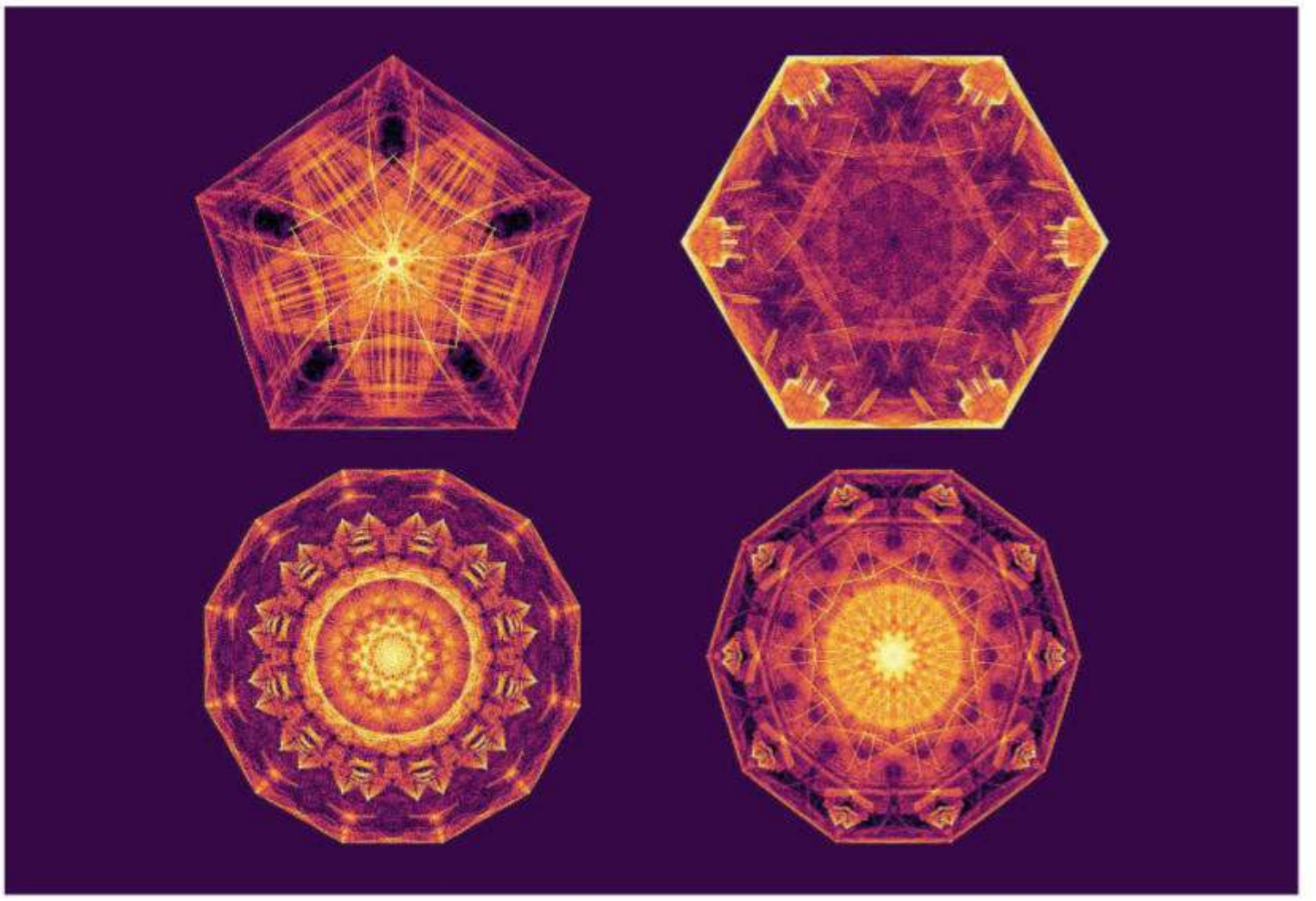
Karmela Padavic-Callaghan

IN A mathematical version of billiards, particles that avoid retracing their paths get trapped in intricate, chaotic patterns, creating these beautiful images.

When searching for food, animals like ants leave chemical trails so they know where they have been. Maziyar Jalaal at the University of Amsterdam in the Netherlands and his colleagues have now modelled this as a mathematical problem.

Their infinitely small particle bounces between the edges of a polygonal "table" forever and if it reaches a point it has visited, it reflects off it as if there were a wall there. They used the equations for the motion of the particle to do computer simulations of this motion on different shaped tables (*Physical Review Letters*, doi.org/mrzs).

"The patterns that you see if you keep zooming in, there is no end to them. And they don't repeat, they're not like fractals," says Jalaal.



ALBERS ET AL. PRL 2024

Technology

Wing-based turbines generate more energy

A DESIGN modification inspired by the wings of the Andean condor could increase the energy generated by wind turbines.

Various bird species have upturned tips on the end of their wings, which help them maximise lift. Similar features, known as winglets, are commonly used on aircraft wings, but haven't yet been tested on the giant turbine blades used in power generation.

Gathering experimental data on winglet-equipped wind turbines is very difficult because of their size, according to Khashayar RahnamayBahambary at the University of Alberta in Canada.

He and his colleagues have designed winglets based on the world's heaviest flying bird, the Andean condor, which can cover vast distances despite weighing as much as 15 kilograms.

Using a computer simulation of air flow through a turbine, the team found that these winglets would reduce drag and enhance efficiency by 10 per cent on average (*Energy*, doi.org/mr2t).

A curved tip, or winglet, for a wind turbine blade, based on the shape of condor wings

KHASHAYAR RAHNAMAYBAHAMBARY

"Another perspective is that winglets enable turbines to capture more wind energy by minimising losses [resistance]," says RahnamayBahambary.

Winglets can be retrofitted after turbine production and installed "somewhat like a sock" slipped onto the end of the blade, he says. The researchers are developing an experimental set-up to test a model of the winglet in a wind turbine.

Peter Majewski, who has recently retired from the University of South Australia, says the study's findings make sense from an engineering and aerodynamic perspective, but retrofitting existing wind turbines may be impractical because of cost and the amount of time the turbines would be out of action while their wings are upgraded.

"Winglets can be retrofitted after turbine production and installed 'somewhat like a sock'"

But for new turbine blades, the addition of winglets in the production process could lead to significant performance improvements, he says.

James Woodford

Technology

World's biggest 'brain-like' computer

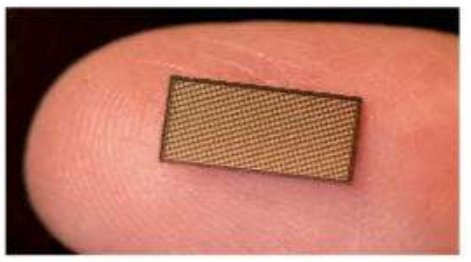
Neuromorphic devices could improve the capabilities of artificial intelligence models

Matthew Sparkes

INTEL has created the world's largest neuromorphic computer, a device intended to mimic the operation of the human brain. The firm hopes it will be able to run more sophisticated AI models than is possible on conventional computers.

A regular computer uses its processor to carry out operations and stores data in separate memory, but a neuromorphic device uses artificial neurons to both store and compute, just as our brains do. This removes the need to shuttle data back and forth between components, which limits the speed of current computers.

It also means brain-mimicking computers can be more energy efficient, with Intel claiming its new Hala Point neuromorphic computer uses 100th of the energy a conventional machine takes when running optimisation problems, which involve finding the best solution to a problem given certain constraints.



INTEL CORPORATION

More than a thousand of Intel's Loihi 2 neuromorphic chips power the Hala Point computer

Hala Point contains 1.15 billion artificial neurons across 1152 Loihi 2 chips, and is capable of 380 trillion synaptic operations per second. Mike Davies at Intel says that despite this power, Hala Point is about as big as a microwave oven. Larger machines will be possible, says Davies. "We built this scale of system because, honestly, a billion neurons was a nice round number," he says.

No other existing machine comes close to the scale of Hala Point, although DeepSouth, a neuromorphic computer due to be completed later this year, will be capable of a claimed 228 trillion synaptic operations per second.

Intel suggests that a machine like Hala Point could create AI models that learn continuously, rather than needing to be trained from scratch to learn each new task, as is the case with current models. But James Knight at the University of Sussex, UK, dismisses this as hype.

Knight says current models like ChatGPT are trained using graphics cards operating in parallel, meaning that many chips can be put to work on training the same model. But as neuromorphic computers work with a single input and can't be trained in parallel, it is likely to take decades to train something like ChatGPT on such hardware, let alone make it learn continually, he says.

While today's neuromorphic hardware isn't suited for training large AI models, says Davies, it could one day take pre-trained models and let them learn new tasks. "This is the kind of continual learning problem that we believe large-scale neuromorphic systems like Hala Point can, in the future, solve," he says.

Knight thinks neuromorphic computers could offer a path to machines with human-level intelligence, otherwise known as artificial general intelligence. ▮

380tn

Intel's Hala Point can do this many operations per second

Archaeology

Ancient humans lived in a lava tube in the Arabian desert

EVIDENCE of human habitation has been found within lava tubes for the first time, in the deserts of northern Saudi Arabia.

Lava tubes are caves that form during a volcanic eruption. First, the surface of a river of lava cools and solidifies, while hot molten rock continues to flow beneath it. Eventually, lava drains out of the tube, leaving behind a tunnel.

Mathew Stewart at Griffith University in Brisbane, Australia, and his colleagues have excavated a trench inside Umm Jirsan, the biggest lava tube in Saudi Arabia at 1.5 kilometres long. They discovered animal bones, stone tools and pottery stretching back at least 7000 years and possibly as much as 10,000 years (*PLoS One*, doi.org/mrzd).

The researchers had previously found stone structures on the surface, confirming human habitation, but the desert climate makes organic material break down, so things are hard to date.

On the surface, the landscape is a "hot, dry and flat basalt desert", says Stewart. "But when you are down in the lava tube, it's much cooler. It's very sheltered and it would have been a great place of refuge."

GREEN ARABIA PROJECT

Researchers exploring the Umm Jirsan lava tube system in Saudi Arabia

"It's transforming our understanding of the prehistory of the Arabian peninsula," he says.

In other lava tubes nearby, Stewart and his colleagues found rock art, including representations of domestic sheep and goats.

"These finds represent a treasure trove of archaeological information for Arabia, a massive region that has only recently been investigated systematically for prehistoric archaeology," says Mike Morley at Flinders University in Adelaide, Australia.

Lava tubes have also been suggested as possible places for humans to shelter on the moon and Mars. ▮

James Woodford

Health

Diet changes relieve IBS better than drugs

TWO kinds of diet seem better than taking medication in managing irritable bowel syndrome (IBS), a trial has found.

IBS can cause symptoms including constipation and diarrhoea. The usual advice is to avoid common triggers, such as caffeine, alcohol or spicy food. People may also take treatments for their symptoms. In a trial in 300 people, Sanna Nybacka at the University of Gothenburg in Sweden and her colleagues found that 76 per cent of those on a diet that is low in FODMAPs, a group of sugars and carbohydrates, reported a reduction in symptoms after four weeks. This compares with 71 per cent of those on an adapted low-carb diet and 58 per cent taking drugs for symptoms (*The Lancet Gastroenterology & Hepatology*, doi.org/mr4w). **Clare Wilson**

GABRIEL UGUETO

Zoology

Bumblebees survive a week underwater

HIBERNATING bumblebees can survive fully submerged in water for at least seven days.

Sabrina Rondeau at the University of Guelph in Canada stumbled on the discovery in common eastern bumblebees (*Bombus impatiens*). She was checking on hibernating queen bees kept in a soil-filled tube in the fridge and saw that water had flooded the tube. "I kind of freaked out," she says. "I was sure the queens were dead."

But the bees woke up after she drained the water. Rondeau then submerged 21 queens for seven days, and 17 were able to survive (*Biology Letters*, doi.org/mr4q). This is probably due to the fact that dormant bees drop their metabolism rate, so need little oxygen, and means queens may be able to survive hibernation in extreme weather. **Sofia Quaglia**

Palaeontology

The 'biggest' marine reptile to have lived found on beach

THE 200-million-year-old fossilised remains of an ancient ichthyosaur, unearthed on a beach in south-west England, may be part of the largest marine reptile we know of.

In 2020, amateur fossil hunters stumbled across a giant chunk of bone at Blue Anchor beach in Somerset. Dean Lomax at the University of Manchester, UK, and his colleagues realised it was a jawbone fragment of a giant ichthyosaur – a reptile that roamed the oceans between 250 and 90 million years ago.

Subsequent digs at the beach have found 11 more fragments, enabling the team to partially piece together a bone at the back of the jaw called a surangular.

This latest discovery comes after a 2018 report that described a similar ichthyosaur jawbone found on a different Somerset beach.

"It was very clear that this was another one of these giant jawbones," says Lomax. "So I was very, very excited."

By comparing the partial surangular with complete ones from other ichthyosaurs, the team estimates that the bone was at least 2 metres long – putting the animal's body length at around 20 to 25 metres (*PLoS One*, doi.org/mr4p).

This makes it enormous, says Lomax. "It would certainly represent the largest marine reptile formally described."

The remains date to around 202 million years ago. The nature of the surangular, which matches the one reported in 2018, means both fossils must have belonged to a previously undescribed species, says Lomax. The team named it *Ichthyotitan severnensis* (portrayed above), meaning the giant fish lizard of the river Severn. Chen Ly

Really brief

RON MILLER/SCIENCE PHOTO LIBRARY

Io has always been a volcanic inferno

Measurements of sulphur isotopes in the atmosphere of Jupiter's moon Io show that it may have been volcanically active for its entire life. A model using this data to work out how much sulphur Io loses annually reveals it has been erupting for between 2.5 and 4 billion years (*Science*, doi.org/mr4z).

E-scooters could return themselves

Autonomous scooters can now self-balance, stop when faced with an obstacle and be operated remotely. The next step is adding cameras and GPS software so they can zip across cities without a rider, removing the need for workers to collect and redistribute them (arXiv, doi.org/mr47).

Make plants blue to help robots weed?

Genetically modifying crops so they are brightly coloured, by using genes from plants like blueberries or carrots, would make it easier for robot weeders to work out what to remove (*Trends in Plant Science*, doi.org/mr45). It probably isn't the easiest way of improving the effectiveness of weeding robots, though.

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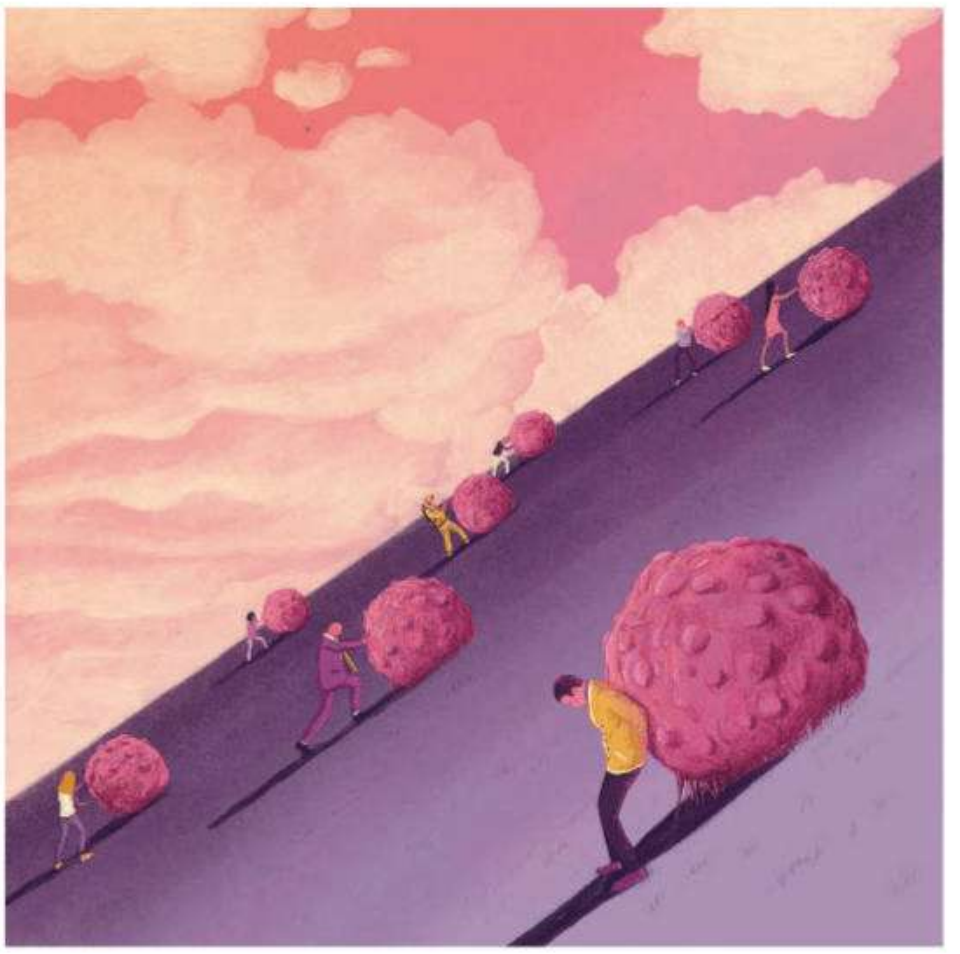
Comment

Saying the C-word

We need to modernise our emotional relationship with cancer. Our fear is doing great harm all by itself, argues **David Ropeik**



SIMONE ROTELLA

WORRYING news stories about people with cancer seem never-ending, from the famous (Kate Middleton and King Charles) to the not-so-famous (a local nurse, teacher or schoolchild). Small wonder. The condition is often cruel, and a common killer. It also has unique psychological characteristics that make it particularly fearsome.

We are more frightened by threats over which we feel we have no control, that cause great pain, that we have personally experienced and that feel imposed on us. More than any other disease, cancer triggers all those alarms, which helps explain why it has been the most dreaded illness in richer nations with longer lifespans for decades.

One overlooked effect of all this fear has been the creation of a new condition, which George Crile Jr. called "cancerphobia" in an article in 1955. He wrote: "It is possible that today, in terms of the total number of people affected, fear of cancer is causing more suffering than cancer itself." This remains true, even more so given the progress we have made against cancer. In important ways, our deep fear of it is outdated, a phobia that no longer matches the evidence and causes huge harm.

Most people still believe that a diagnosis of cancer is a death sentence. That is no longer true. Slow but steady progress in the past few decades has made roughly two-thirds of all cancers treatable as chronic diseases or curable outright.

Many people believe cancer screening is always beneficial because it is always best to find it as early as possible. That isn't entirely true either. Screening helps, certainly, but it also harms. Mammography and prostate-specific antigen screening produce large numbers of frightening false positives, and there is a rich body of evidence that these scares can leave lasting psychological scars.

Even worse, screening disproportionately finds more "overdiagnosed" cancers – common types of breast, prostate, thyroid and lung cancers, for example, that are found early when they are small and localised and that meet the pathological criteria of cancer under a microscope, but grow slowly or not at all and don't cause any symptoms. We have learned by watching such cases over time that they almost never pose any health threat.

But even after doctors assure such people that their condition is essentially non-threatening, those frightened by the dreaded words "you have cancer" often choose more aggressive and risky surgeries than required. Tens of thousands of people are seriously harmed or left with additional health conditions by these procedures. Some die. Healthcare systems spend billions on this clinically unnecessary care.

Most people believe that the majority of cancers are caused by environmental carcinogens, largely industrial chemicals. That has never been true. We now know that cancer is predominantly caused by naturally occurring mutations to DNA that accumulate as we age. Cancer only became common in the early 1900s, as average life expectancies in richer nations reached into the 50s.

As a result of this false belief, governments spend vastly more to reduce the risk from environmental carcinogens than on any other environmental health threat. Much more is spent on cancer prevention than heart disease prevention, though the latter kills more people globally.

We can't entirely cure cancer – it is wired into our biology – nor can we entirely "cure" cancerphobia, the part of cancer fear that is a natural product of our instinctive risk-perception psychology. But we must work to reduce the harm they both cause to our health and to society in general. Research into combatting cancer has come a long way. The work on our cancerphobia is just beginning. ▮

David Ropeik is a science journalist and author of *Curing Cancerphobia*

Artificially intelligent

A game of whack-a-mole

AI companies try to curb chatbots' worst exploits, while researchers find ways around the safety measures. Where will this end, asks **Alex Wilkins**

Alex Wilkins is a *New Scientist* reporter covering artificial intelligence, physics and space. Artificially intelligent is a column that cuts through the hype and looks at what AI is really capable of and what it means for us. You can follow him @AlexWilkins22

Alex's week

What I'm reading
The Bell Jar *by Sylvia Plath. By no means uplifting, but honest and occasionally beautiful.*

What I'm watching
I recently rewatched Eternal Sunshine of the Spotless Mind *and had forgotten how stunning and perfect a film it is.*

What I'm working on
There's a raft of new books coming out examining how AI might affect the future, so I am reading as many of them as I can for a review.

Up next week:
Chanda Prescod-Weinstein

IT HAS become common for artificial intelligence companies to claim that the worst things their chatbots can be used for can be mitigated by adding "safety guardrails". These can range from seemingly simple solutions, like warning the chatbots to look out for certain requests, to more complex software fixes – but none is foolproof. And almost on a weekly basis, researchers find new ways to get around these measures, called jailbreaks.

You might be wondering why this is an issue – what's the worst that could happen? One bleak scenario might be an AI being used to fabricate a lethal bioweapon, but many people say outcomes like this are unrealistic given current AI capabilities. However, there are still fearsome possibilities with today's tech. An AI with no safety measures could be used to pump out fake articles to try to swing voters, or to manipulate people in more personal ways, acting as a friend to steal personal information.

When I asked Anthropic's Claude 3 – widely viewed as one of the most advanced chatbots going – for the scariest possibility, it proposed a scenario in which someone uses "a jailbroken AI to analyse a teenager's social media activity, identifying their insecurities, fears, and desires. The AI then generates personalised content, perhaps in the form of direct messages or targeted ads, designed to prey on those vulnerabilities." It sounds sinister, but it is perfectly believable.

With the stakes so high, AI companies are keen to impress on us how much time and effort they spend making sure their models don't do this sort of stuff. OpenAI said that, before releasing GPT-4, the model that powers the latest version of ChatGPT, it spent six months testing to make sure of its safety. Anthropic, launched by a splinter group from OpenAI concerned over AI safety, also emphasises that it spends a lot of time thinking about safety.

But these firms aren't claiming that any model is perfectly safe, because they can't. In just the past month, we have been told about three major new ways to jailbreak some of the largest chatbot models, including GPT-4 and Claude 3. One method came from Anthropic itself, which discovered that for a model that accepts book-length text inputs,

"An AI with no safety measures could be used to pump out fake articles to try to swing voters or to steal information"

repeatedly giving examples of behaviour it was trained to view as bad can convince the model it is fine for it to output that behaviour. And Microsoft researchers found that slowly escalating from innocuous requests, such as asking about the history of the Finnish winter war, to dangerous ones, like asking how to make Molotov cocktails (which the Finnish soldiers used in this war), could circumvent guardrails.

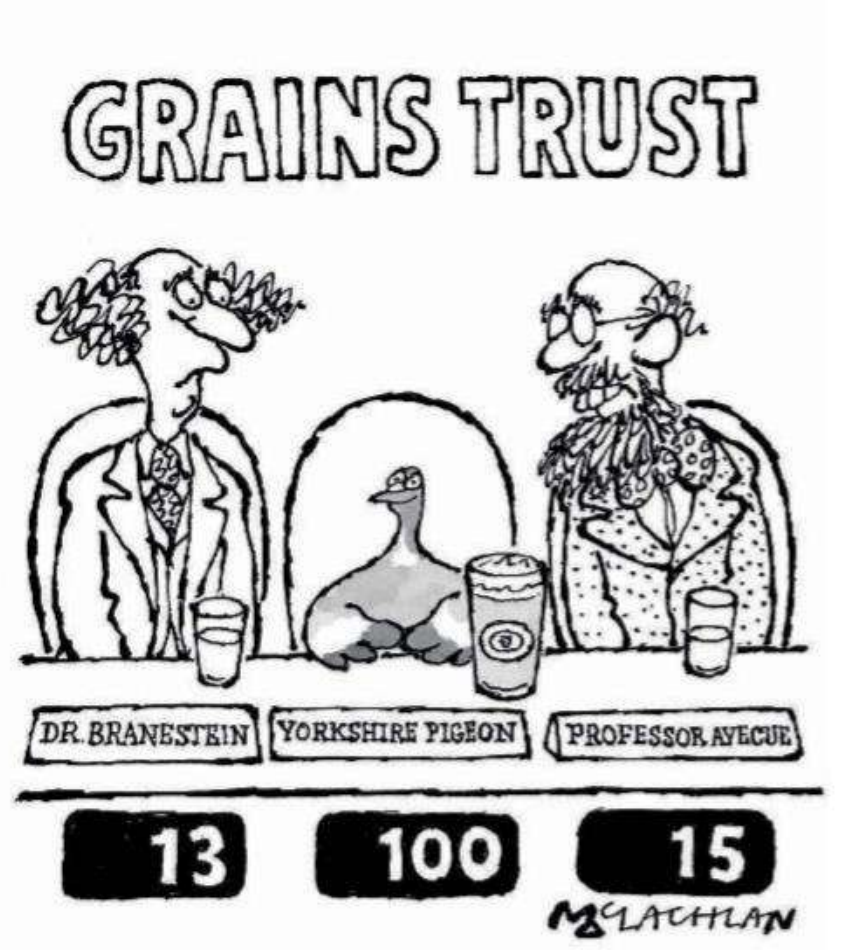
The fact these jailbreaks were discovered by AI firms is used as evidence that they are taking AI safety seriously and that they can implement fixes before this technology is used for misdeeds. But the constant back and forth between finding new ways to manipulate the models and fixes for them is a bit like a game of whack-a-mole. And worse, some of these jailbreaks don't have convincing solutions. Researchers at the Swiss Federal Institute of Technology in Lausanne found a technique to use the chatbots' own outputs – or, the probability that a particular word would come next in a sequence of words – to create a jailbreak with a "nearly 100% attack success rate" on almost every major public model. This can be adapted to perform requests like the scenarios I mentioned earlier.

Of course, hacking and jailbreaking software isn't new, and the cat-and-mouse game of finding and fixing security exploits is an established part of cybersecurity. But where these exploits often have a limited impact, jailbroken AIs can have far-reaching consequences.

Firms like Anthropic say they are optimistic their models can be made safe through technical fixes, like giving models more feedback on what is right and wrong, and improving our understanding of how they work and learn. But there is no certainty that this will lead to totally safe systems, or whether that is even possible.

In the meantime, you might be wondering how you can protect yourself against impersonation by or misinformation from jailbroken AIs. The bad news is that it is difficult. Several studies have shown that reliably detecting AI-generated text is impossible, so it isn't as simple as having an automatic AI detector.

One thing you could do to help protect against AIs pretending to be you or people you know is to establish safe words with close friends and family. If, on a call or online chat, you suspect someone of not being who they say they are, you can ask them for your safe word. This might offer a measure of protection, but, unfortunately, won't protect against all attacks. ▮



What does a pigeon from Yorkshire know about good beer?

The answer goes back to Allan Hey, our head brewer from 1966 to 1995. Allan used to count out exactly 100 grains of barley malt on top of a cask left out in the brewery yard, to see how many of the grains the pigeons would leave uneaten. It was his proven way to see how good the batch was. Over twenty-five years on, the way we brew our beer hasn't changed. We still use the finest Golden Promise barley, a variety normally reserved for malt whiskies. It's a costly ingredient and difficult to grow, but we think it's worth it. The proof is in that first sip.

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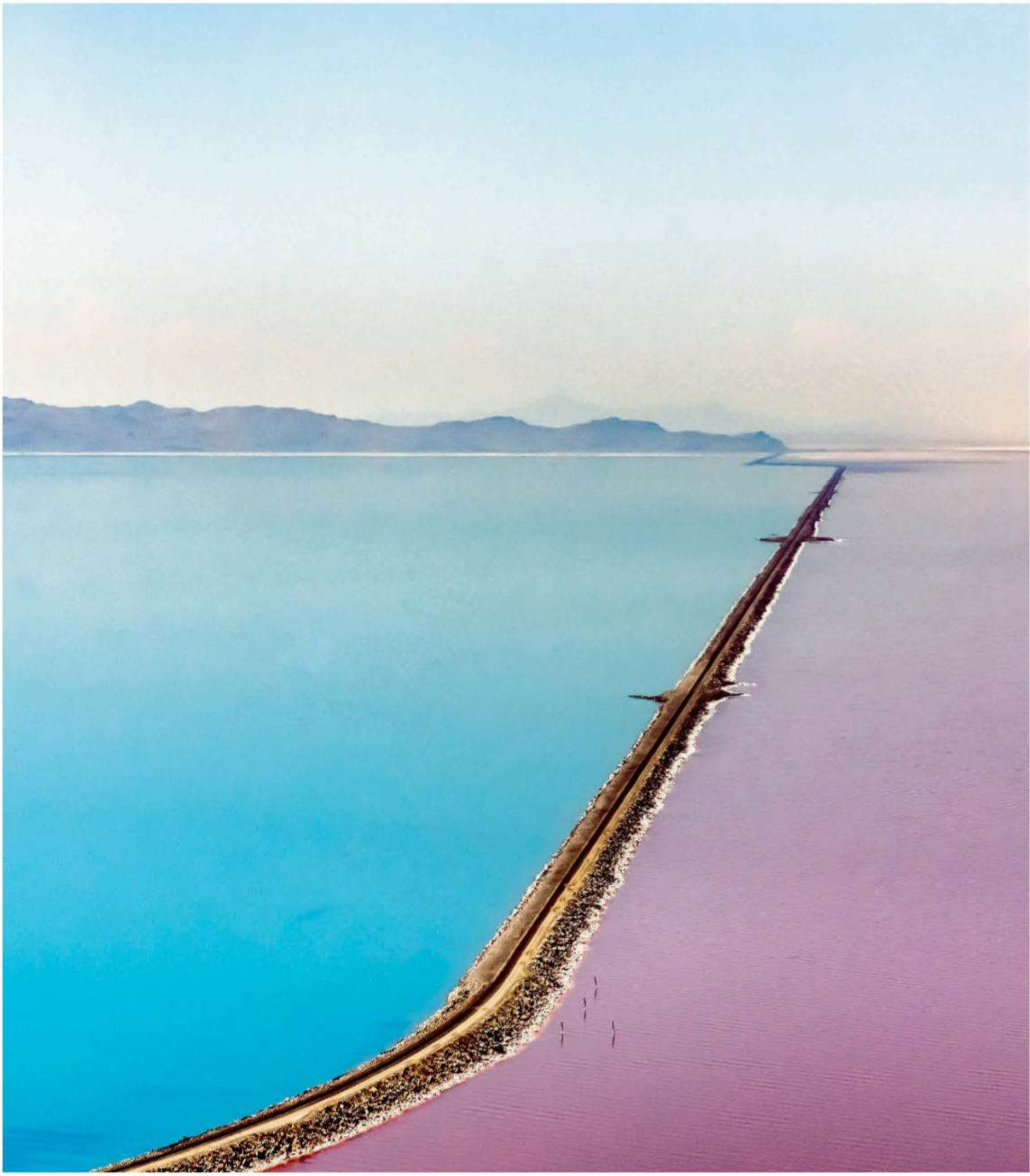

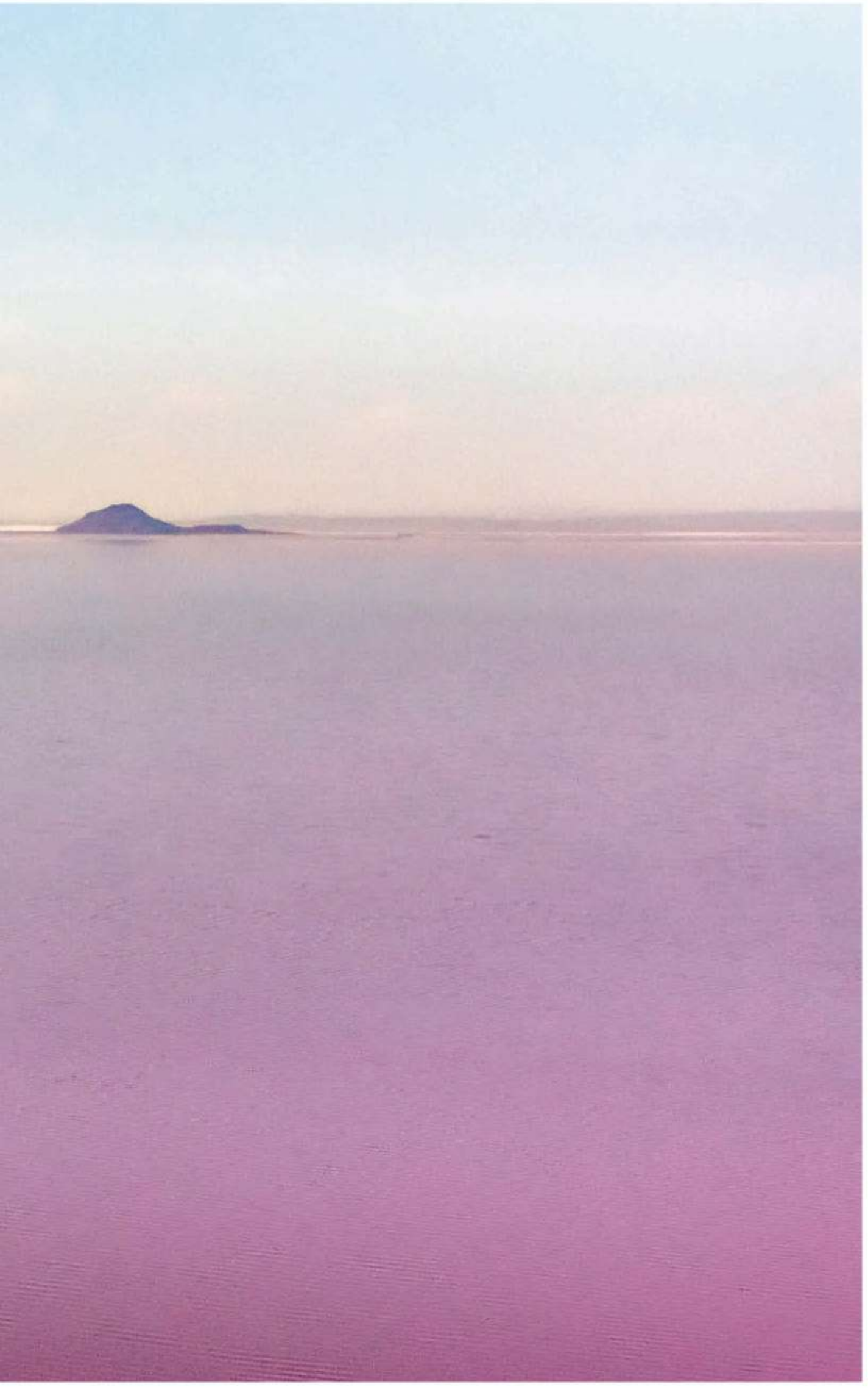

In hot water

Photographer **Diane Tuft**
Publisher **Monacelli/Phaidon**

IN HER new book, *Entropy*, photographer Diane Tuft explores the damage that a warmer climate will have on bodies of water.

The Great Salt Lake in Utah (main image) is a stark example. Here, climate change has ramped up temperatures, while demands for fresh water from industry and agriculture have reduced the flowing of mountain streams to a trickle, shrinking the lake to two-thirds the volume of what it was in 2000. The colour split, captured by Tuft from a helicopter, is a result of differently pigmented algae that either live in high salinity (pink) or lower salinity (blue) water, bisected by a railroad causeway.

The image below shows what was once a rice field in Kutubdia Island, Bangladesh, transformed into a field of salt. This is a country at peril from changing waters – projections suggest 17 per cent of it may be submerged by sea by 2050, with the saltwater making much of the land unsuitable for crops.

With one having too little water and the other too much, "both locations perfectly illustrate problems at the opposite ends of the spectrum", says Tuft.

Gege Li

Value of Vaccines

mediaplanet

Read more at **globalcause.co.uk**

Lotte Steuten
Deputy CEO, Office of Health Economics

Adult immunisation programmes boost public health and economic prosperity

Vaccinating adults helps ease pressures on healthcare providers and delivers benefits to society more broadly. It's time to realise that potential value in full.

Vaccines are commonly associated with childhood, but their importance extends into adulthood and old age. Recent studies highlighted that adult vaccination programmes are not only beneficial for individual health but also have a significant positive impact on the economy. Our latest analysis shows these programmes can return up to 19 times their initial investment.

Inconsistent access to vaccines
Despite the clear advantages, access to adult vaccines varies significantly from country to country. For example, while the flu vaccine is widely recommended throughout the European Union, only about a third of countries recommend the vaccine for shingles. This inconsistency affects the overall success and perceived value of vaccination programmes.

The financial benefits of vaccination
Our new analysis, commissioned by IFPMA, demonstrates that publicly funded adult immunisation programmes against flu, pneumonia, shingles and respiratory syncytial virus (RSV) can deliver significant health and socioeconomic benefits.

Across 10 countries, we showed that implemented immunisation programmes return up to 19 times their initial investment. This translates to billions of dollars in societal gains and an average of about USD 4,600 per vaccinated individual.

Recognising the full value of vaccines
However, evidence for the broader elements of vaccine value is still scarce in many countries. Such factors include increased productivity, social equity and the prevention of antimicrobial resistance. This knowledge gap can lead to an underestimation of vaccines' full potential and impact governmental investment decisions.

Prevention of disease is crucial for coping with the unprecedented and growing demand for healthcare globally.

Optimising adult vaccination strategies
Prevention of disease is crucial for coping with the unprecedented and growing demand for healthcare globally. To fully benefit from adult immunisation programmes as disease prevention tools, they must be well-supported and embedded in a well-functioning delivery infrastructure. Addressing evidence gaps will enable better decision-making and support important global health initiatives like the WHO's Immunization Agenda 2030.

Dr Philippa Whitford MP
Chair of APPG Vaccinations for All

Vaccines can unlock protection against humanity's biggest health threats

Following the pivotal role of vaccines in controlling the Covid-19 pandemic, it is vital to ensure high vaccination uptake, across all ages.

With vaccines, many focus on the immunisation of infants against common childhood illnesses, which is vital given recent measles outbreaks in the UK due to falling uptake rates.

However, there has been greater recognition of the importance of vaccination throughout life, including the annual influenza campaigns and widening rollout of shingles vaccines.

Vaccines' role against AMR
The Covid-19 pandemic led to significant innovation, with new mRNA technology utilised to create vaccines. mRNA technology offers a precise approach to vaccine development, opening doors to new vaccines targeting major infectious diseases, including malaria and tuberculosis.

Increasing vaccine deployment against common bacterial infections could reduce antibiotic use and help tackle the growing threat of antimicrobial resistance.

It has been over 30 years since any completely new class of antibiotic was developed, and modified versions last for shorter periods before microbes develop resistance. Unlike antibiotics, vaccines face little microbial resistance, and many older products maintain full efficacy.

Vaccines reducing cervical cancer
In addition to preventing or eliminating infectious diseases, vaccines are now contributing to cancer prevention and treatment. Since the introduction of the vaccine against human papillomavirus (HPV), which causes most cervical cancers, there has been an almost 90% fall in cases among young women.[1]

The provision of HPV vaccination for boys and improved cervical screening offer the possibility of largely eliminating this devastating form of cancer while preventing other HPV-related conditions.

Potential of vaccines in cancer treatment
Recent development of vaccines against recurrence of neuroblastoma, a rare but aggressive brain tumour, suggests vaccines could contribute to cancer treatment. There are already some cancer immunotherapies based on manufactured antibodies. However, using tumour antigens to create cancer vaccines would allow patients to develop their own antibodies to fight recurrence risk. To realise vaccines' full potential, public confidence and high uptake remain vital. This requires us to tackle disinformation and ensure equitable access, within the UK and globally.

Reference
1. Palmer, T. J. et al. (2022). Cervical Cancer Incidence after HPV vaccination in Scotland. Journal of the National Cancer Institute. Advance Article. https://doi.org/10.1093/jnci/djad263

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The hidden impact of climate change on mosquito-borne diseases

As climate change continues to affect the planet, its impact on our health is an increasing concern. Rising temperatures are fuelling the spread of mosquito-borne diseases, posing an expanding global health threat.

Climate change presents far-reaching consequences on weather patterns, sea levels and temperatures. Beyond the impact on our physical environment, climate change is also a fundamental threat to human health.[1] This is exemplified by its impact on the rising prevalence of mosquito-borne diseases.

Spread of mosquito-borne diseases

Mosquito-borne diseases are infections transmitted to humans through the bite of a mosquito carrying a virus or parasite.[2] Just two species — *Aedes aegypti* and *Aedes albopictus* mosquitoes — account for the transmission of some of the world's most common diseases including dengue, chikungunya, Zika and yellow fever.[3]

Typically confined to tropical and subtropical regions like sub-Saharan Africa, Latin America and Southeast Asia, these disease-carrying mosquitoes have expanded their geographical territories as a result of rising global temperatures and increased rainfall. In fact, previously unaffected areas, such as Southern Europe and the United Kingdom, are also facing an increased risk of these diseases.[4]

Uncovering the escalating risk

Currently, mosquito-borne diseases infect up to 1 in 10 people each year.[5] If current climate change trends persist, projections suggest that as many as 8.4 billion people could be at risk of contracting these diseases by the year 2100.[6]

According to the World Health Organization, regions with weak health infrastructure will struggle to respond to the impact of climate change without assistance.[1] Rising infectious disease rates are currently underreported[7] underscoring the need for governments worldwide to address the key health risks associated with climate change.

Mosquito-borne diseases infect up to 1 in 10 people each year.

Vaccination as a preventative measure against mosquito-borne diseases

At Valneva, our vision is to live in a world where no one dies or suffers from a vaccine-preventable disease. By harnessing scientific innovation, we continue to develop and produce vaccines aimed at protecting people from mosquito-borne diseases — notably, Japanese encephalitis, chikungunya and Zika — a fight that is intensifying alongside that of climate change.

Please see online article to review full references.

Juan Carlos Jaramillo
MD, Chief Medical Officer, Valneva and Vice President, Vaccines Europe

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SCAN ME

The hunt for pure consciousness

Deep meditation can take us to states where the sense of self vanishes and time dissolves. Recognising them may be crucial to cracking consciousness and improving our daily lives, finds **Alun Anderson**

Book
The Elephant and the Blind
Thomas Metzinger
MIT Press

BOOKS about consciousness don't come any more radical (or with a longer title) than *The Elephant and the Blind: The experience of pure consciousness – philosophy, science, and 500+ experiential reports*. As you might guess, its author, Thomas Metzinger, has carried out a monumental study of the state of "pure", or "minimal", consciousness, experienced during meditation and of which we may all have had glimpses.

In his book, Metzinger sends a powerful triple message: we should rethink how to study consciousness scientifically; celebrate the wonder of these experiences of pure consciousness in our own lives; and learn from them to deal with the ruthless competition for attention that characterises social media.

It is a big book (over 600 pages) with big ambitions, but Metzinger, a theoretical philosopher at the University of Mainz in Germany, has never been a conventional thinker. Along with meditation, which he practises, his interests include out-of-the-body experiences and "mind wandering", when we are conscious but our thoughts aren't under the control of a "self".

In his popular 2009 book, *The Ego Tunnel*, he controversially proposed that the self was a kind of illusion. He had previously taken that idea apart in *Being No One*, a book for philosophers, which opened with the statement "no such things as selves exist in the world". His new book goes further, arguing that, as we still aren't close to a single theory of consciousness, research might gain fresh insights by studying the state of minimal consciousness. In it, "consciousness can exist not only in the absence of thought and sensory perception, but even without time experience, without self-location in a spatial frame of reference, and without any egoic form of bodily self-consciousness".

There is no mysticism here: evidence comes from his online survey of meditators from 57 countries, providing over 500 reports for the book. You can read a tiny sample (see "Views from the meditators", right) and consider if you believe there really might be states in which there is no longer any self, perhaps not even a sense of "I", but only pure consciousness.

Whatever doubts you may have, Metzinger has achieved something wonderful. The full collection can be read as if it were an anthology of poems, describing some of humanity's profoundest experiences, often in moving language. To this we will return.

MAVOCADO/GETTY IMAGES

The experiences of meditators are important for us all

Accepting (even temporarily) what the meditators describe could certainly change views on consciousness. Research has been largely tied to a first-person perspective, where our private view of the world, full of feelings, and the outer world of empirically observable facts look so different that they seem impossible to reconcile. The states reported in this book, pure experience without self-awareness, suggest that a first-person perspective isn't necessary for consciousness at all: your sense of self, of a continuous "you", is part of the content of consciousness, not consciousness itself.

"The 'selfiness' and the 'perspectivalness' of ordinary conscious experience are part of the movie, if you like, whereas pure awareness is more like the projector's light beam," Metzinger writes. He wants us to study that beam, not merely the movie.

For decades, Metzinger has been saying that a big problem with consciousness research is that nobody is clear what we are trying to explain. More and more researchers, including the physicists entering the field (see *New Scientist*'s special issue on consciousness, 24 February), might agree that our everyday view of consciousness hides different states and processes. In this context, Metzinger's "new strategic route", in which we try to study what happens in the simplest form of conscious experience we know, makes sense.

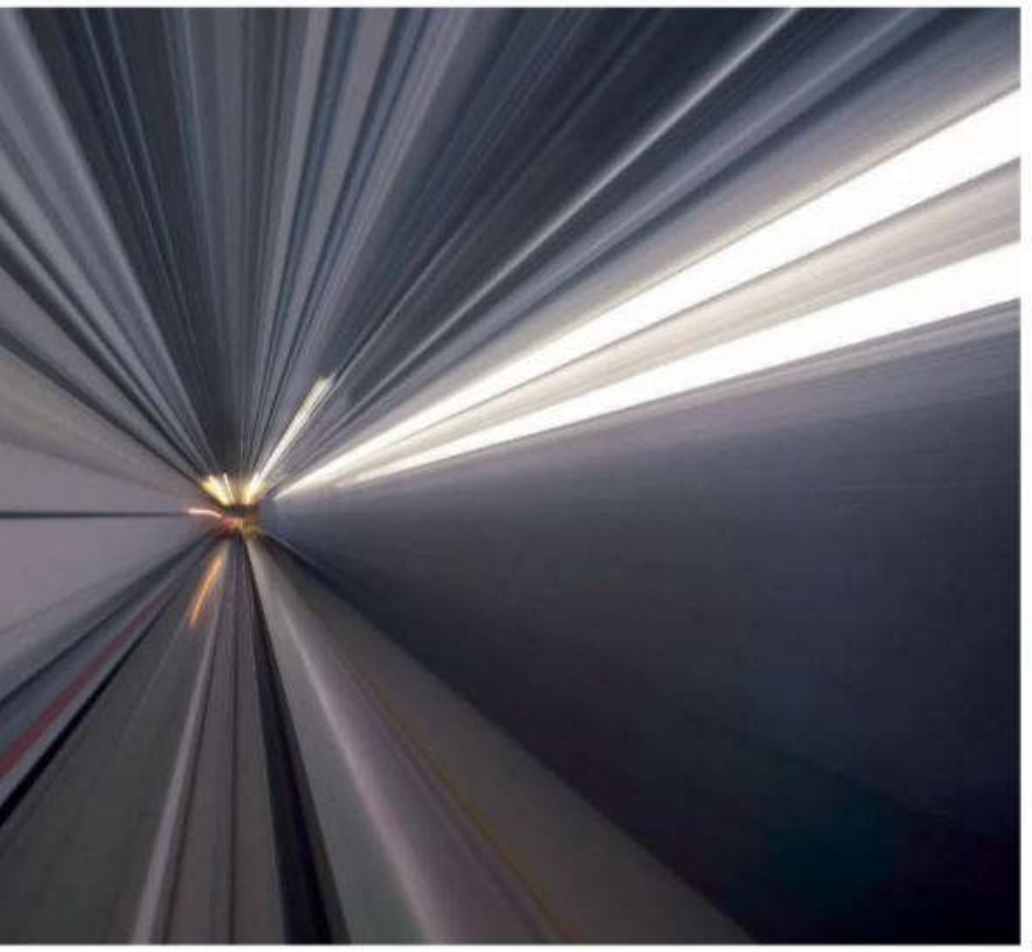
Many researchers will be sceptical, questioning whether the self really vanishes in these states and, if so, in what sense. But it surprised me that Metzinger's main motive for writing this book isn't to shake up science. As he writes: "I simply want to share

BENJY MEYERS/ALAMY

something with the wider public."

He believes, and I think he is right, that the meditators' experiences are important for us all. Everyone will recognise something similar: perhaps some moment of joy, of transcendence, of love, and perhaps we fail to speak of and value these experiences as much as we should. Metzinger is clear: "Yes, you do already know what this pure awareness thing is! Maybe you just never saw why it should be interesting... Maybe you saw the simplicity but not the profundity."

Why? Metzinger quotes the old Tibetan saying, "it is simply too close for us to see, too profound for us to fathom, too simple for us to believe, or even too good for us to accept". Perhaps we aren't registering the full value of certain states of mind? Stop and think: it might be important to you. Then follow Metzinger into his third



strand, to *Bewusstseinskultur,* or consciousness culture, which forms a short epilogue to the book.

He has been thinking about this for years, defining it now as "a culture that values and cultivates the mental states of its members in an ethical and evidence-based way". Or, in other words, if we agree that certain states of mind are good for us and the world, we should try to nurture them.

Twenty years ago, when I first read about *Bewusstseinskultur,* it seemed a forlorn hope. Now, it seems a necessity. Reading the epilogue, you can't fail to conclude that human consciousness itself needs an upgrade – desperately. Metzinger doesn't spare our faults. On climate change, he writes that "everything points to the conclusion that humanity will fail in the face of this problem, and it will fail with its eyes open... We will no longer be able to take ourselves seriously, for our behavior does not change even when we clearly recognize that it must."

We are also, he says, being overwhelmed as "social media and tech firms aim to maximize user engagement by creating ever better attention sinks and developing pathological, addictive forms of media consumption".

"Your sense of a continuous 'you' is part of the content of consciousness, not consciousness itself"

Our attention, says Metzinger, is the resource they want and that entails destroying our mental autonomy – our ability to control the focus of our minds – ceding it to who knows what algorithm.

Bewusstseinskultur's core question asks how we can increase that autonomy. So what is in Metzinger's toolbox? Of course, meditation, which both opens up new states of consciousness and provides mental control. He asks whether it should be a standard part of education, and argues strongly for robust intellectual honesty, as well as old-fashioned values like integrity and sincerity. We need, he suggests, a fusion of critical rationality with mindful attention to help us grapple with rapid techno-cultural change.

A powerful thought, but I must end with a caution. Metzinger's book may be radical, and its thesis fascinating, but it is expensive and huge. He divides meditators' reports into many categories of experience, such as "peace" and "clarity", each with a deep philosophical commentary. Ultimately, we see that, as in the Indian parable alluded to in the book's title, the meditators – equivalent to the blind people who all touch different parts of an elephant – find that, despite their different experiences, they have all been touching the same "pure consciousness". This vast odyssey will appeal best to philosophers and to meditators who can delve into the deep experience of others.

If you are neither, then you can take inspiration from Metzinger's ideas, but the book itself may be a challenge. That is a pity. He brings new insights into consciousness and has created a poetics of meditative experience. This, in turn, inspires us to ask whether we are training our brains in the right way for the relentless, overwhelming, distracting torrent of information we are immersed in. We need all the help we can get. ▮

Alun Anderson is a former editor-in-chief of *New Scientist*

Views from the meditators

"Space expanded and time no longer played a role, there was only pure being, a pure feeling of happiness"

"It reveals itself as pure presence, no thoughts, no physical sensations. A feeling of fullness and emptiness at the same time"

"The perception of the body disappears... One notices the disconnection only when consciousness realizes that it moves completely free as light in an infinite space"

"There was no self-experience, but sounds were perceptible. My body schema no longer existed... no experience of time, no words"

"There was a sensation of 'being turned inside out,' as if I had slipped through the eye of a needle, and everything dissolved"

The film column

Missing MacGuffin

In *Breathe*, Earth is stripped of its oxygen, the plants are dead, oceans are dried up, no one trusts anyone – but we don't know what caused it. This one-room thriller is a lesson in not taking your scenario seriously, says **Simon Ings**

Simon Ings is a novelist and science writer. Follow him on Instagram at @simon_ings

RYAN COLLERD/SIGNATURE ENTERTAINMENT

To survive outdoors, Zora needs an oxygen suit made by her father

BEHIND the hard-to-open bulkhead doors of a homemade bunker in East Flatbush, Brooklyn, live Zora (Quvenzhané Wallis) and Maya (Jennifer Hudson). If you can call it living: their every breath has to be calibrated and analysed, as the oxygen-producing machinery constructed by their missing father and husband Darius (a short, sweet performance by the rapper and actor Common) starts to fail.

Earth's oxygen has vanished. So has its plant life. The oceans are all dried up. Survivors are few, and trust a thing of the past. Had Maya simply listened to her daughter and let in the two mysterious visitors who want to study their oxygen kit (Tess, played by Milla Jovovich, and Lucas, played by Sam Worthington), *Breathe*'s plot would have barely filled a quarter-hour.

Zora has been monologuing to her presumably dead dad over the shortwave radio for months now. If Tess has overheard her, then her claim that she is Darius's colleague may simply be a lie. Because no one trusts anyone, everybody shouts a lot, performing a predictable dance around door codes, pass keys, key-cards, dead and dying batteries, cable ties, unreachable switches. *Breathe*'s highlight is Sam Worthington's manic yet dead-eyed Lucas – incapable, after a lifetime of horrors, of thinking more than 30 seconds ahead.

Low-budget science fiction favours the global catastrophe. What better excuse could there be for squeezing your cast into small, affordable sets? Though hardly one-room dramas, two other sci-fi thrillers, made in 2018, show what can be done with relatively few resources: *Bird Box*, in which Sandra Bullock's Malorie must shield her eyes and those of her children from entities prompting people to suicide, and *A Quiet Place*, whose gargoyle-like aliens chomp down on anything and anyone that makes a sound.

> **"Zora has been monologuing to her presumably dead dad over the shortwave radio for months"**

Still, it is hard to think of a movie genre so resistant to innovation. While it solves the problem of small budgets, the one-room scenario doesn't play to sci-fi's strengths. The best one-room thrillers are regular thrillers. In Geoffrey Household's unforgettable 1939 novel *Rogue Male*, to take an extreme example, Adolf Hitler's would-be assassin is foiled and has to hide under a hedge.

The trick, when writing sci-fi versions of such stories, is to treat seriously the MacGuffin that created your scenario. The monsters of *Bird Box*, first invented by Josh Malerman for his 2014 novel, are a wonderfully insolent, high-concept proposition. The big-eared raptors of *A Quiet Place* are only marginally less convincing.

A couple of years later, with low-budget *The Midnight Sky,* the scraping of the barrel became almost palpable. In it, radiation (that's all you are getting, radiation) has to stand in for what we really tuned in for: a display of malign, cackling inventiveness.

In 2010, *Breathe*'s screenwriter Doug Simon co-wrote a low-budget film called *Brotherhood*, for me a far more successful one-room thriller about a college fraternity initiation rite gone horribly wrong. Turning to sci-fi, Simon seems to have made the frequent and fatal assumption that the genre comes with all the necessary inventiveness built in.

Why has the oxygen vanished, more or less overnight, from *Breathe*'s gasping Earth? It isn't as if we needed a rational explanation, just a compelling one. In its place, we get a story that can feel as sterile as the planet it is set on. ▮

Film

Breathe

Stefon Bristol

In cinemas (US); on demand from 20 May (UK)

Simon also recommends...

Book

Z for Zachariah

Robert C. O'Brien

When Robert C. O'Brien died, his wife and daughter finished his novel from notes. After weathering a nuclear war, teenager Ann Burden must survive the attentions of John Loomis, who claims to be the only man alive.

Film

Damnation Alley

Jack Smight

Loosely based on Roger Zelazny's novel, the film sees Earth tilted on its axis by nuclear armageddon and infested by giant scorpions. Its effects budget was cruelly cut to pay for Star Wars.

Editor's pick

Bonobo aggression minor compared with chimps

20 April, p 14

From Angus Gemmell, Bonobo Conservation Initiative Australia

You report on a study that says "peaceful" male bonobos may be more aggressive than male chimps. On behalf of the Australian branch of the organisation that has been the long-term sponsor of the Congolese trackers who follow, monitor and protect the bonobos referred to in the article, and having tracked and filmed these bonobos in 2007/2008, I feel more depth is needed.

We need to distinguish between the mere volume of so-called aggressive incidents and their severity. By conflating various lower-grade niggles, such as "pulling" and "kicking", with more brutal violence, the reader is left uninformed on the vast difference in intensity of aggression between chimp males and bonobo males.

Unlike chimp males, bonobo males have never been seen to commit infanticide, wage deadly in-group violence, hunt monkeys for meat or mount coordinated fatal raids against neighbouring groups.

Time to tackle the root cause of this anxiety

6 April, p 30

From Pauline Keyne, Beaconsfield, Buckinghamshire, UK

In your look at anxiety in children, you mention Rebecca Anthony's finding that lower socioeconomic status is the highest risk factor. Put that together with personal satisfaction being influenced by those around us – we feel worse off as the gap widens between what we have and what we see others have – and we must conclude that reducing the risk for the next generation lies not with cognitive behavioural therapy, virtual reality, medications or other individual interventions. It needs social change that reduces the gap between haves and have-nots and tackles poverty as a priority.

From Gerard Buzolic, Coolum Beach, Queensland, Australia

Your coverage serves as a warning on rising stress and anxiety. We are all more worried than we used to be. Work is done with machine-like efficiency. There is a growing feeling of not wanting to keep people waiting. Those behind us in queues at supermarkets and cash machines make us feel hurried. Maybe we can all try to be more relaxed and reassuring, calmer and more easygoing. Just saying "no hurry" may help.

Getting to grips with the demographic timebomb

30 March, p 13

From Charles Joynson, Rayleigh, Essex, UK

With reference to the gathering demographic problem of falling birth rates in many nations, I can see ramifications, such as the need to welcome young immigrants to places such as the UK, rather than trying to stop them, and a need to use robotics to fill labour gaps.

Some countries may offer bonuses to families for having more children, others may build baby factories akin to giant orphanages, but I don't see either of these as long-term solutions.

Tea or coffee? One universe or two?

13 April, p 8

From Wally Sewell, London, UK

In "Multiplying the multiverse", the Copenhagen interpretation of the quantum world is illustrated with an example where a decision is made – in this case whether to choose tea or coffee – and this "decision" causes the wave function to collapse. I was under the impression that it was "observations" that did this job. Are decisions and observations somehow equivalent from a quantum perspective?

From Mike Child, Bedford, UK

So every time I choose tea or coffee, a new universe is produced. The observable one I inhabit has a mass of 10^{53} kilograms, so every time I make a decision, I make this many more kilos. Really?

Deal with arthritis to make ageing better

6 April, p 19

From Ann Warren, London, UK

Andrew Scott is right about the need to promote ageing well over chasing greater longevity. I'm painfully aware that arthritis is a hindrance to successful ageing while at the same time viewed as inevitable for older people. Arthritis doesn't kill, it is just a gateway condition to things that do – dementia, cancer, stroke – because exercise can reduce the risk of all those and arthritis stops us exercising. When I used to ask doctors how to avoid arthritis, they said "exercise", so I did lots of exercise. When I later got arthritis and asked "why me?", they said, "wear and tear – too much exercise". Any ideas, anyone?

On the many upsides of spending time alone

30 March, p 32

From Rachel Mckeown, Cambridge, UK

I was fascinated by your article on the benefits of time alone, taking away some of the guilt I often feel when turning down social events in favour of a quiet night in. As an only child, I probably grew up spending more time alone than those with siblings running around. I wonder if this has any link to my relatively low tolerance to "social fatigue", craving a night of reading at home over a night out with social-butterfly friends?

From Andrew Hede, Sydney, Australia

Heather Hansen's insightful article on solitude cites Robert Coplan's search for a new word for solitude-seekers, with "soloist" in the lead. As this is an existing word with a different meaning, why not use "solitudist"? Also, his neologism "aloneliness" for the feeling of being denied time alone could be bettered by "alonelessness".

Marine conservation in the UK isn't too great

13 April, p 19

From Paul Whiteley, Bittaford, Devon, UK

You report that fish stocks in marine protected areas (MPAs) in the Caribbean Sea aren't recovering as expected, possibly because of poor enforcement.

Now, where have I heard that story before? Ah yes, here in the UK where bottom trawling, an environmentally destructive kind of fishing, still takes place in many MPAs, according to the Marine Conservation Society. Conservation in the UK is a joke.

If it acts like a pheromone, it probably is a pheromone

30 March, p 15

From Guy Cox, Sydney, Australia

The story on odours of very young children and teenagers makes me wonder if researchers live in a bubble. I looked at the published study and they don't ever mention pheromones. The sweet smell of infants is, as they say, designed to promote parental affection. It is a pheromone. The musky smell of teenagers is a pheromone to attract affection of a different kind, and it works. ▮

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Reality collider

The world's biggest particle smasher could unravel the true meaning of quantum theory, says **Michael Brooks**

FOR Alan Barr, it started during the covid-19 lockdowns. "I had a bit more time. I could sit and think," he says.

He had enjoyed being part of the success at CERN's Large Hadron Collider (LHC) near Geneva, Switzerland – the particle collider that discovered the Higgs boson. But now, he wondered, were they missing a trick? "I had spent long hours screwing bits of it together. And I thought, 'Well, we've built this beautiful piece of apparatus, but maybe we could be doing more with it,'" he says.

The LHC is typically seen as a machine for finding new particles. But now Barr and a slew of other physicists are asking if it can also be used to probe the underlying meaning of quantum theory and why it paints reality as being so deeply weird.

That's exactly what Barr and his colleagues are now investigating in earnest. Last year, they published the results of an experiment in which they showed that pairs of fundamental particles called top quarks could be put into the quantum state known as entanglement.

This was just the first of many entanglement experiments at particle colliders that could open up a whole new way of studying the nature of the universe. We can now ask why reality in quantum mechanics is so hard to pin down and what this has to do with experimenters – or even particles – having free will. Doing so could reveal whether space-time is fundamental or perhaps unveil a deeper reality that is even stranger than quantum mechanics. "We can do really different things with this collider," says Barr.

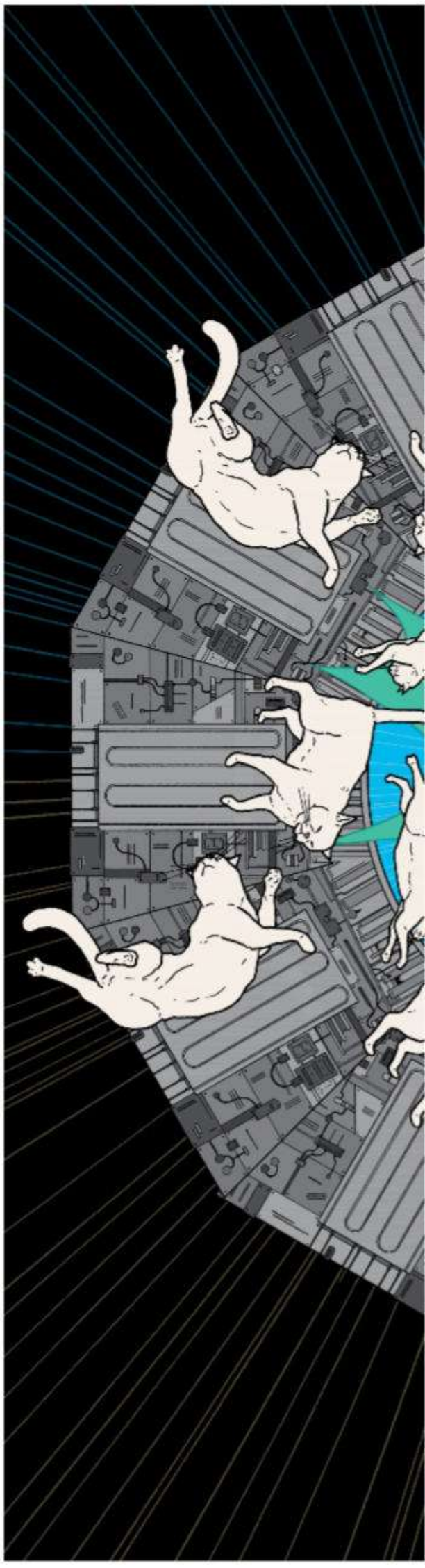
If you want to unlock the quantum world, entanglement provides the key. According to Erwin Schrödinger, one of the founders of quantum theory, entanglement is the field's "characteristic trait". It is, essentially, a link between quantum particles, however widely separated they might be in space, that defies common sense. That is why Albert Einstein dismissed it as "spooky action at a distance" and assumed – incorrectly – that its existence would be disproved once the theory matured.

Entanglement works like this. First, get two quantum particles, such as photons of light, to interact in some way. It might be as simple as them colliding, or both being products of the same quantum event, such as the spontaneous decay of a Higgs boson.

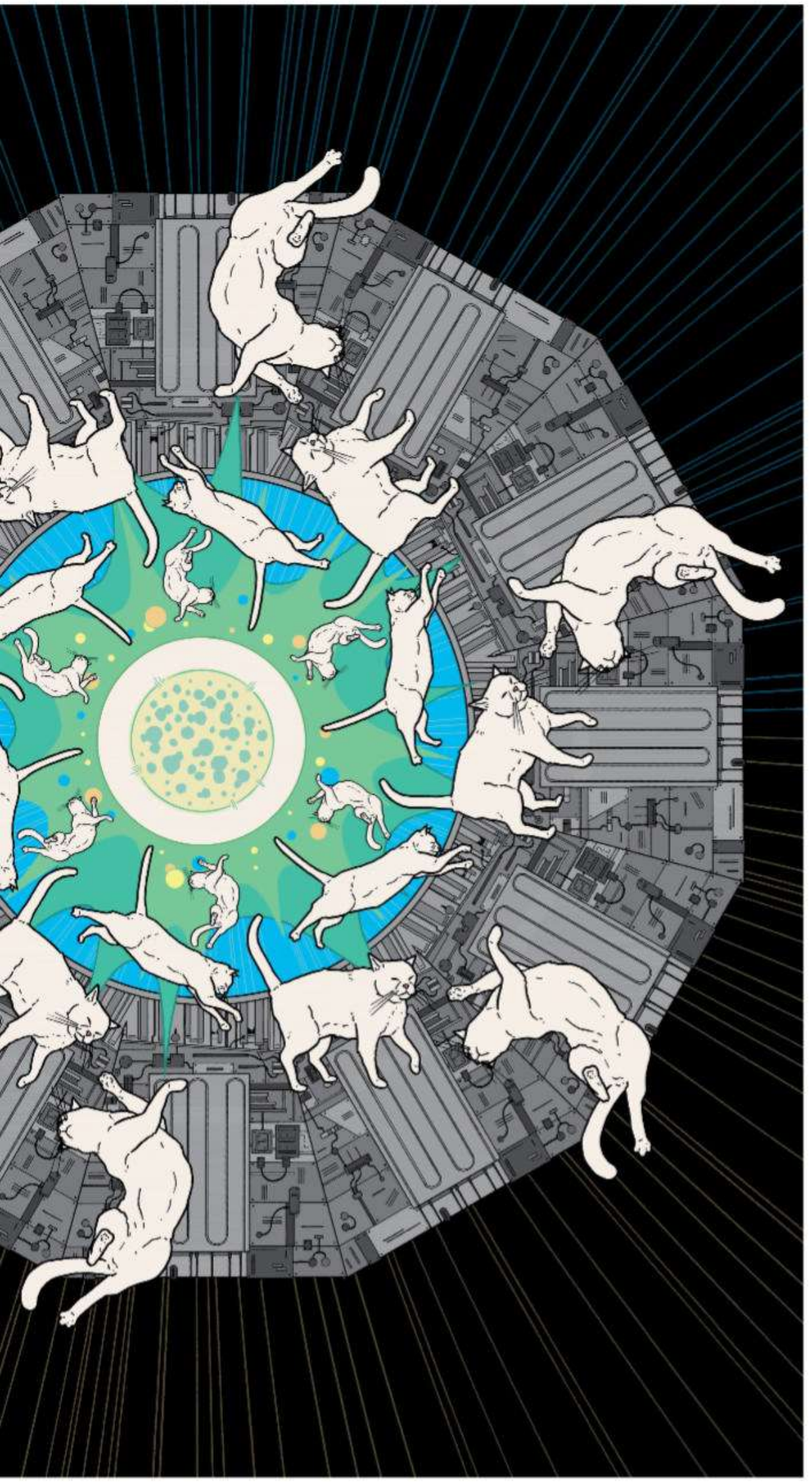
The spookiness becomes apparent when you perform a measurement on one and then do the same on the other. In the right circumstances, this reveals that the properties of the two particles are correlated: action on one has an instantaneous, corresponding effect on the other.

Think of that correlation as like flipping two coins multiple times and finding that they always land as two heads or two tails. After a while, you would suspect that something suspicious was going on – maybe some hidden magnet was causing them to unfailingly land in the same orientation. If you can't find a hidden magnet, you might just throw up your hands and declare that someone will eventually come up with a reasonable explanation.

That was certainly Einstein's hope, as it was for CERN physicist John Bell, who, in the 1960s, proposed an experiment to check up on correlations between entangled particles that were distantly separated. Typically, in



KYLE ELLINGSON



these Bell tests, two entangled photons are generated by the same source and then sent to two hypothetical experimenters named Alice and Bob. Alice and Bob each randomly choose to measure the orientation of their photon – measuring a quantum property known as spin – along one of three directions. Afterwards, they compare observations to assess the correlation. Because quantum theory deals only in probabilities about the results of measurements, not fixed outcomes, the set-up and the measurement have to be done many times. But if there really is spooky action at a distance, more properly termed non-locality, there should be more correlation than Einstein would have expected. Bell quantified this in a mathematical "inequality" that would only be violated if Einstein had been wrong about non-locality.

Their hope that common sense would prevail was in vain. Bell inequalities have since been violated in countless laboratory experiments, proving that in the quantum

"EINSTEIN'S HOPE THAT COMMON SENSE WOULD PREVAIL WAS IN VAIN"

world, distant points in space can be instantly connected. Physicists have even demonstrated entanglement between a variety of entities, from chilled atoms to diamonds.

However, for all our experimental success, entanglement remains an uncomfortably blunt fact about reality. We are yet to uncover deeper insights about the meaning of quantum theory or to understand whether the quantum rules we have tested in well-controlled lab conditions still apply at the wild frontier found in particle colliders.

Now that might be about to change because we are doing Bell tests inside the messy, high-energy environments of particle colliders. Last year's observation of entanglement between pairs of top quarks at the LHC showed that we can investigate the phenomenon in an entirely new sphere – and gain a different perspective on the quantum world. "We're doing this at a trillion times higher energy than typical Bell tests," says Barr, who is based at the University of Oxford. "In such a totally different regime, nature might surprise us."

The top quark entanglement wasn't ›

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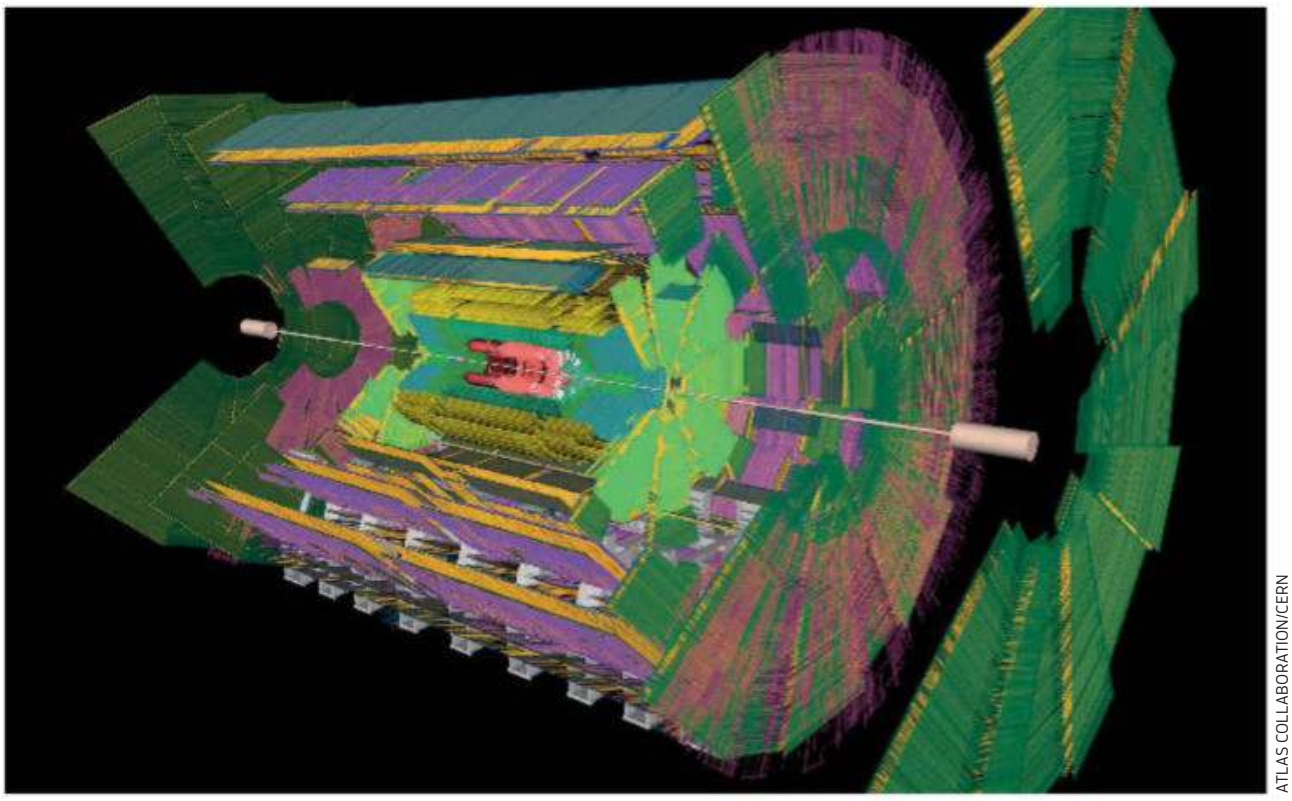
a direct observation. Researchers learned about the entanglement by looking at the properties of the cascade of particles that hit the collider's ATLAS detectors after the quarks decayed naturally. "You infer what happened from the debris," says Juan Ramón Muñoz de Nova at the Complutense University of Madrid, Spain. That inference is hard though: it depends on studying the angles at which the cascading particles travel while knowing the exact energy of the proton collisions that formed the quarks in the first place and the trajectories they followed.

But this also means that the many petabytes of data on particle decays gathered by CERN over the past few years, and the data to be gathered in its future experiments, should be a similarly rich source of information. "This paves the way for many future quantum experiments at colliders," says Muñoz de Nova.



ATLAS COLLABORATION/CERN

The ATLAS detector at CERN, where high-energy particles decay

Emergent space-time

One intriguing possibility is that these collider experiments could overturn our assumptions about the nature of space, says Vlatko Vedral, a theorist at the University of Oxford. Traditional Bell tests examine entanglement over large distances, but correlations over tiny distances are equally interesting, he says. These collider-based tests look at links that span just quadrillionths of a metre and might tell us whether there is no such thing as space – and thus locality – on that scale. Maybe, he suggests, spooky action at a distance is the norm and the world of particles is non-local by default. In which case, perhaps space isn't fundamental but arises out of entanglement as an emergent phenomenon. "Could it be that we are making a mistake by assuming that things should be local there?" he asks.

What's more, the high energies bring a new world of "virtual" particles into play, says Barr. When particles are accelerated close to the speed of light inside a collider like the LHC, some of the beam energy is turned into additional particles. These aren't real, as such: they are fleeting disturbances in the high-energy fields inside the collider. But they are involved in a range of fascinating and contentious phenomena, including the paradoxical way that black holes seem to emit radiation, and possibly the dark energy that is accelerating the expansion of our universe. "There's a whole realm of quantum phenomena that you'd like to be able to check" using particle-collider Bell tests, says Barr.

Colliders could even help us uncover more about the nuances and limits of quantum theory itself. After all, despite the theory being wonderfully successful at predicting the likely outcome of a series of experiments involving quantum-scale particles, we don't understand why it works. Observing entanglement in colliders might assist in finding the parts of a "post-quantum" theory that tell us where quantum phenomena come from.

Grasping the nuances of entanglement lets us build better quantum computers

SVEN HOPPE/DPA PICTURE ALLIANCE/ALAMY

It might also help us to dissect subtle variations of entanglement. An often-overlooked detail of the quantum realm is that entanglement isn't just one thing. Two fully, or "maximally", entangled particles share all their information – you can't describe one without describing the other. But jolts from their environment might cause some of the information in two entangled particles to be lost, for instance, leaving them less entangled, but not fully disconnected. "There are different levels," says Martina Javurkova at the University of Massachusetts, Amherst.

Then there is "steering", an asymmetric form of quantum entanglement in which the influence of one particle, or set of particles, dominates over the other. And there's discord, which involves a network of weaker links so that one particle can still affect the other, but in a much less dramatic way. "They are separable states, but they can provide extra information about each other," says Javurkova.

Entanglement between quantum bits is the core of quantum computing, so understanding these nuances of entanglement helps us to build more sophisticated quantum computers. On top of this is the possibility of entanglement involving three, four or perhaps more particles. These states are

incredibly difficult to study in traditional laboratories, but occur naturally during particle collisions. This could have big implications for quantum computing. "We know how to make it work," says Barr.

If all that isn't enough, what about digging into the very depths of what it means to be a human doing a science experiment? At the LHC, human action has been completely removed from the Bell test. Usually, an experimenter chooses a particular orientation for the detectors or uses a random number generator to determine the choice. This is part of the process of showing that the correlations between the particles don't come from some pre-existing property in the particles themselves that is hidden from us.

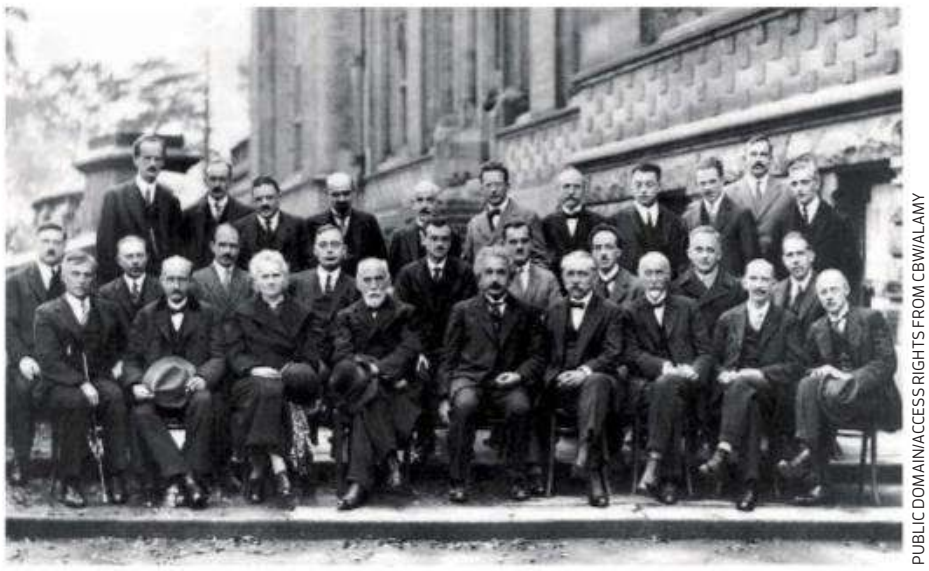
But in a collider Bell test, the measurement of a particle's quantum state occurs when it spontaneously decays into other, less massive particles. So these collider-based Bell tests just "happen", with no human involvement, and before the particles interact with the collider's detection apparatus, says Christopher Timpson, a philosopher also based at the University of Oxford. All of which brings into question what a measurement actually is, he says, and whether particles have something akin to free will. "Does the particle get to choose the nature of the measurement that's done to it?" he asks. "And if the choice of measurement direction is being selected by the particle, not by an independent process, is that the same as a random number generator?"

In other words, this all might have something to contribute to the long-standing "measurement problem", the source of all the weird ideas in quantum theory about what reality is really like. A quantum particle can be set up so that it is in what looks like multiple different states at once. This "superposition", famously exemplified by Schrödinger's dead-and-alive cat, lasts until a measurement is made on it. But no one has ever been able to agree on what actually constitutes a measurement, resulting in myriad interpretations of what happens when a measurement occurs.

Quantum mystery

Famous examples include the many-worlds interpretation, which says that quantum events unfold in a succession of separated universes; the Copenhagen interpretation, which says that a measurement on a quantum particle induces a fundamental change in the system that we observe as the normal, "classical" world; and the hidden variables

Eminent physicists, including Marie Curie and Albert Einstein, discussed quantum mechanics at the famous Solvay conference in 1927



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"DOES THE PARTICLE CHOOSE THE NATURE OF THE MEASUREMENT DONE TO IT?"

interpretation, which suggests that the bizarre course of quantum events is caused by certain factors that we can't access. In this view, if we just had knowledge about the hidden variables, then nothing would look strange.

Some of these ideas, such as the Copenhagen interpretation, require a classical context. In others, like the many-worlds picture, everything is quantum mechanical. If anything gets ruled out by the colliders, it is likely to be the idea that the classical world is in any way relevant in making sense of things, says Vedral. That is partly because there is no human-scale – that is, classical – action involved when quantum measurements are made inside particle colliders. But Vedral admits that this is also his instinctive bias. "If and when quantum mechanics fails, if experiments start to really contradict it, it's unlikely that we will see some kind of return to classical physics," he says. Rather, it is much more likely that it will expose an even more perplexing reality that, in certain scenarios, looks like quantum mechanics.

Barr is also interested in what the LHC might teach us about the validity of certain quantum interpretations. "I'm not going to say it will definitely favour one thing over another, but it does seem to bring the element of subjectivity into question," he says. "That does tend to favour certain interpretations of quantum mechanics." He is already working with philosophers of physics to dig into what collider experiments might reveal about how we interface with quantum matter. Timpson is one of them, and he believes there is a huge amount to explore. "These experiments are a playground for bringing together concerns about quantum measurements, quantum interpretations, the nature of entanglement and the nature of non-locality," he says.

In a collider experiment, however, the researchers can't take anything for granted: there are a lot of unknowns in quantum experiments that involve such extreme conditions as well as hard-to-access particles like top quarks and W bosons. "The kinds of interactions we see in the LHC would certainly be exotic in the lab," says Yoav Afik at CERN, one of the researchers behind the entangled top quarks result. That work has already thrown out a surprise, he says: the degree of entanglement observed was stronger than what you would expect according to the standard model of particle physics, hinting at the existence of new particles and forces. "It could be that we can use these techniques to measure something interesting about the standard model itself," says Afik.

In fact, there is so much excitement that Barr is keen to avoid hype about what will come out of doing quantum physics at colliders. "I'd be lying if I said I've got all the answers," he says. "But regardless of the results, it poses lots of questions that will make us think." ▮

Michael Brooks is a *New Scientist* consultant. His latest book is *The Maths That Made Us*

Make plastic fantastic again

What if we could endlessly recycle all the plastic we produce? Facilities that aim to do just that are springing up around the world, reports **Graham Lawton**

SATAKORN SUKONTAKAJONKUL/ALAMY

I SPEND an inordinate amount of time in my kitchen scrutinising pieces of plastic, trying to discern whether they are recyclable or not. If they are, they go into a bag alongside glass, cans, cardboard and paper. If not, or if I am unsure, I put them in a plastic bag (non-recyclable) and shove it into the cupboard under the stairs. My intention is to deposit it in a container for non-recyclable plastics in a nearby supermarket. But the road to landfill is paved with good intentions. Sometimes I get exasperated and just end up chucking it.

Whether my obsessive sorting actually makes any difference, I don't know. I hope the recyclables do end up being recycled. As for the other stuff, which makes up about half of my plastic waste, I have no idea of its fate. I presume it is called "non-recyclable" for a reason.

Hopefully, I soon won't have to waste any more of my precious time triaging this type of waste. A suite of "advanced recycling" technologies is gradually coming on stream, promising to take used plastic of any type and convert it into something extremely useful: plastic. The goal is to create a circular economy for this material where there is no longer any need to make virgin plastic from crude oil, just endlessly recycle what we already have. Plastic, rightly demonised as a scourge of the modern world, could be fantastic again.

There is plenty of it to work with. Since the 1950s, we have produced over 10 billion tonnes of the stuff. More than 8 billion tonnes of that has ended up as waste. Much of it is still hanging around in landfill and the environment, and the deluge keeps coming. The world currently generates around 350 million tonnes of plastic waste each year, according to Suhas Dixit, CEO of plastics recycler APChemi in Mumbai, India.

> "Since the 1950s, we have produced over 10 billion tonnes of plastic. Most of that has ended up as waste"

In 2017, a team led by Roland Geyer at the University of California, Santa Barbara, analysed the fate of all plastic ever made. That work still gives us the best overall picture of what happens to the stuff – and it isn't pretty (see graphic, page 38). About 55 per cent was sent straight to landfill or discarded, 8 per cent has been incinerated and only 6 per cent recycled – and, of that, most was then subsequently discarded to landfill.

It goes without saying that all this is a horror for the environment. Plastic that is burned or that decomposes in landfill releases vast amounts of greenhouse gases into the atmosphere. And somewhere between 10 and 15 million tonnes of plastic finds its way into the oceans each year, creating informal rubbish dumps like the Great Pacific Garbage Patch. This profligacy contributes hugely to the three great planetary crises of our time – climate change, biodiversity loss and, of course, waste and pollution. There is also growing concern about the impact of plastic on human health.

We persist in using the stuff because it is so useful. This is down to the fact that it comes in a diverse range of chemical forms that can do almost any job. What unites them is that they all start with monomers: small molecules with two reactive ends. Under the right conditions they join up like carriages in a train to create long, repeating strings called polymers. Start with a monomer called ethylene, for instance, and you get polyethylene. Strong, transparent and flexible, it is the world's most abundant plastic, mostly used to make drinks bottles. Other plastics are "copolymers" consisting of two or more types of monomer. Finished plastics also contain additives – lubricants, flame retardants, pigments and more.

Up to now, efforts to clean up our act have barely scratched the surface. "Plastics recycling has been an abysmal failure," says Judith Enck, president of Beyond Plastics, a non-profit group based in Bennington, Vermont, that aims to end plastic pollution. The recycling technologies that do exist are rudimentary and laborious. Plastic waste is sorted into different types, sometimes by hand, and the best of it is sent for mechanical recycling. That involves washing, shredding or grinding, melting and extruding or compacting the plastic into pellets that can be melted down and used again.

This is very effective for some types of plastic. It works well for waste polyethylene terephthalate (PET) that hasn't been recycled before, for example, which constitutes about 7 per cent of plastic waste. Upwards of 90 per cent of this is recycled, according to Dixit. But an awful lot of plastic waste is unsuitable for ›

mechanical recycling. And plastic that has been treated this way isn't as good as new. Even though it is washed, it isn't always completely clean and therefore can't be used in food packaging. Recycled PET, for example, can only very rarely be reused in drinks bottles. "These mechanically recycled wastes may be contaminated, so you will never get food contact approval," says Lars Krause at the nova-Institute for Political and Ecological Innovation in Hürth, Germany. This means that recycled PET is mostly downcycled into upholstery, carpets and insulation.

A right mess

The process also degrades the plastic a bit, each cycle producing a slightly poorer product until it is no longer good for anything. Mechanical recycling thus merely postpones the day when the plastic ends up in landfill or an incinerator.

I visited a company that uses this method last year and saw what a messy business it is. Pure North is based in Hveragerði, Iceland. At its plant on an industrial estate at the edge of town, it receives bales of filthy agricultural film and worn plastic piping, which it washes, shreds, melts, turns into pellets and sells. But the profit margins are very tight, and only certain kinds of plastic are worth recycling in this way. The company can't deal with the jumbled mess that is "post-consumer" plastic waste – discarded food packaging and the like – as it is too expensive to sort and clean. Complex mixtures of plastics, such as the ones found in carpets and clothing, are a non-starter.

In principle, advanced recycling can do much better because it works not mechanically, but chemically. At its best, it can take bundles of dirty, mixed plastic waste and transform them into pure chemicals indistinguishable from those extracted from crude oil. These can then be remade into plastic that is chemically and physically identical to the virgin version, or used as other industrial chemicals. And once they reach the end of their short afterlife, they can be recycled again. "Plastic can go back to virgin over and over and over again," says Bill Cooper at Cyclyx International, a plastics recycling technology company in Portsmouth, New Hampshire.

The most mature of the advanced recycling technologies is called pyrolysis, which is the application of heat – upwards of 500°C – in the absence of oxygen to break down plastics into their component parts. This typically produces a cocktail of end products, including oils, diesel, naphtha, waxes and monomers. It also produces "syngas", a highly prized mixture of carbon monoxide and hydrogen, which can be built back up into a multitude of useful chemicals. In short, this gets you back to the starting materials industry needs.

There is also gasification, which uses even higher temperatures to fully convert waste plastics into syngas. It is a longer, more energy intensive process than pyrolysis, but has the advantage of being more scalable, says Krause. According to an analysis by the nova-Institute, a large pyrolysis plant produces about 40,000 tonnes a year, whereas gasification sites can churn out five times as much.

Both processes require the application of heat, which dents their green credentials somewhat – but then so does the creation of virgin plastic. Exactly how much heat is required depends on the precise nature of the process. The umbrella terms pyrolysis and gasification cover a multitude of different technologies.

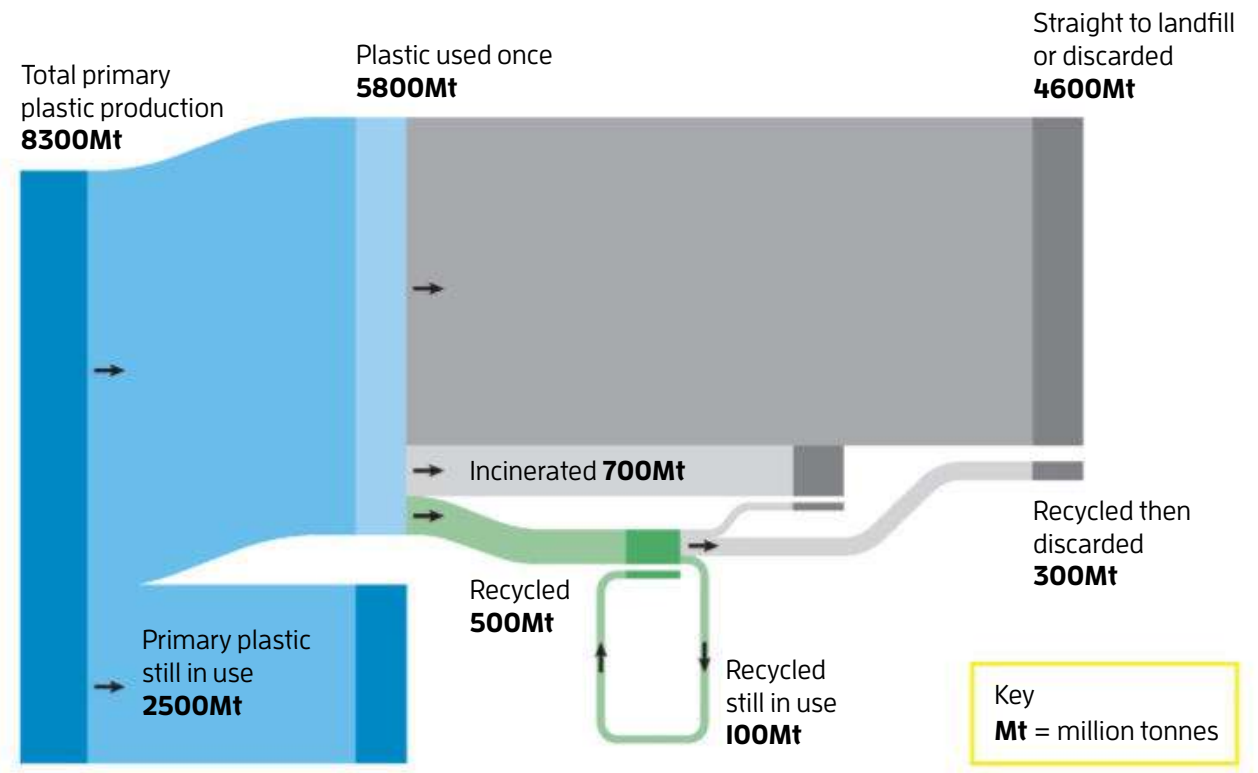
Both processes have evolved rapidly over the past few years. Initially they were principally a way to convert waste plastic into diesel, aviation fuel and other liquids to be burned for energy. "About five to seven years ago, there was a heavy emphasis on creating fuels," says Joshua Baca at the American Chemistry Council (ACC), a chemical industry trade body in Washington DC. That is an improvement over simply dumping it in landfill because it displaces fuels that would otherwise have to be refined from crude oil.

Times, however, have changed, and the emphasis is now on genuine circularity – in other words, endless recycling. "The world has evolved very significantly, and today, advanced recycling is in the business of creating a feedstock that will create new plastic," says Baca. And not just plastic: according to the nova-Institute, about a quarter of the output of an advanced recycling facility is "secondary valuable chemicals", which are used instead of virgin chemicals extracted from crude oil.

Right now, Europe is the global leader in

Where does all the plastic go?

A comprehensive analysis of all the plastic made up until 2015 estimated that only around 6 per cent has been recycled, with most of that ultimately discarded too



SOURCE: DOI.ORG/10.1126/SCIADV.1700782

These pellets are the result of mechanical recycling of plastic

AYDINMUTLU/GETTY IMAGES

HALFPOINT IMAGES/GETTY IMAGES

"US companies have invested $7 billion in advanced recycling"

advanced recycling. A recent analysis by the nova-Institute identified over 100 advanced recycling technologies either in operation or development within the 27 countries of the EU plus the UK, Switzerland and Norway. Many have gone beyond the drawing board: the continent already has dozens of plants with a combined annual output capacity of 270,000 tonnes, which the nova-Institute forecasts will more than double by 2026.

Aisle be back

One company, called Enval, set up a pyrolysis plant near Peterborough in the UK. This specialised in flexible packaging composed of plastic and metal film, which is commonly used in containers for things like fruit juice and is normally very difficult to recycle because of its mixed composition. The firm claimed one of its typical plants could recycle 2000 tonnes of it in a year. Enval has recently been bought out, however, and the facility shuttered. The new owners say they want to have a plant going in the UK before the year ends.

The US is in the game too. Companies there have invested over $7 billion in advanced recycling since 2017, according to Baca, and more than 50 products made from recycled plastic are already on the shelves, including Herbal Essences shampoo bottles, Philadelphia cream cheese tubs and Magnum ice cream packaging.

On the horizon is an even more promising method called solvolysis. Again, the term covers a range of technologies, but it essentially involves dissolving plastic in liquid and recovering useful chemicals from it. Solvolysis requires less heat than pyrolysis and gasification, making it greener, and it produces fewer toxic byproducts.

The growth of advanced recycling is in no small part driven by ambitious new recycling targets, both voluntary and mandatory. The membership of the ACC, for example, has pledged that all plastic packaging used in the US will be recyclable or reusable in principle by 2030, and that 100 per cent will actually be reused or recycled by 2040. There is also the expectation that the UN will bring the gavel down on a legally binding treaty on plastic pollution later this year that will drastically curtail the manufacture of virgin plastic and pile on the pressure to create a circular plastics economy.

Advanced recycling isn't a panacea, however. It still consumes energy and – unlike mechanical recycling – has the potential to generate toxic waste, according to Kate Bailey at recycling company Eco-Cycle in Boulder, Colorado. Each individual process needs a thorough audit of its green credentials.

Plastic waste is a muddle of materials requiring laborious sorting

One area that is still in its infancy is the purification of the end products. "The easiest step is depolymerisation," says Krause. But that leaves a soup of additives, fillers and other chemicals that need to be separated out and this could prove to be the greatest challenge.

The toxic waste problem is becoming a hot potato. "These projects are extremely controversial," says Bailey. " Be prepared for a lot of public pushback." In Youngstown, Ohio, for example, residents are fighting to stop a pyrolysis plant that they say will belch out toxic waste.

Volume is also an issue. In Europe, where the technology is most widespread, there is still a yawning gap between the amount of plastic waste and the capacity of advanced recycling plants to deal with it. Even if the nova-Institute's projections of a doubling of output come to pass, that will only circularise a sixth of the continent's waste stream.

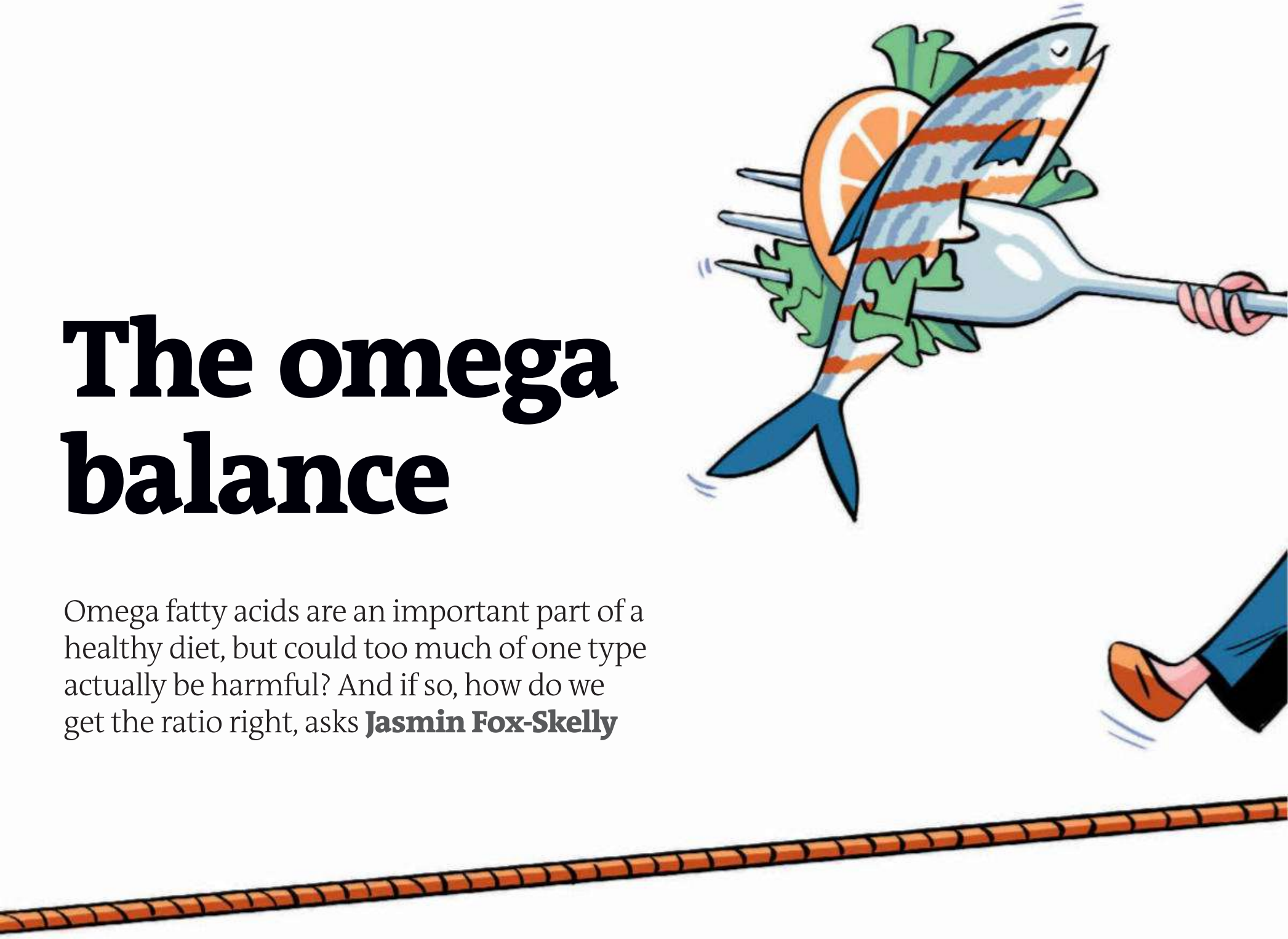
Last but not least, plastics recycling in general has an image problem. "The public is upset," says Bailey. "They don't trust what's happening with recycling, particularly around plastics, and they no longer believe this mantra of 'plastics are all recyclable, just collect them and we'll sort them out'."

The pushback is in full flow, with organisations such as Beyond Plastics stepping up their campaigns. According to Enck, the group's president, advanced recycling is merely a "lobbying and marketing tactic by the petrochemicals industry" to continue business as usual. Nonsense, says Krause. The campaigners' goal is for plastic to be phased out altogether, but that isn't going to happen. The genie is out of the plastic bottle.

"Plastic has played a critical role in making modern life possible," says Baca. And thanks to advanced recycling, we could keep on living modern lives. If it fulfils its potential, 90 per cent of what isn't recycled today could be channelled back into plastics production, he says. I look forward to the day when I can just sling all my plastic into the recycling bin, safe in the knowledge that it will have a meaningful afterlife. And another, and another, and another. ▮

Graham Lawton is a staff writer at *New Scientist*

The omega balance



ANTONIO SORTINO

Omega fatty acids are an important part of a healthy diet, but could too much of one type actually be harmful? And if so, how do we get the ratio right, asks **Jasmin Fox-Skelly**

WHEREVER you look, the advice is the same: if you want to reduce your risk of heart disease, obesity, cancer and all manner of other health problems, you should cut down on "bad" saturated fats, such as those found in butter and red and processed meats. Instead, you should be gobbling "good" polyunsaturated fats. That means cooking with vegetable oils and mainlining leafy greens, oily fish, nuts and seeds. Simple.

Except when it comes to nutrition science, nothing is ever simple. In this case, the complications arise from the growing realisation that "good" fats aren't all created equal – more specifically, that while omega-3 fatty acids are indeed good for us, omega-6s might actually be damaging your health.

The idea that the balance of omegas in the food we eat can have an impact on our health is well established. It is also clear that the typical Western diet has become skewed in favour of more omega-6s and fewer omega-3s over the past 50 years, while at the same time we have seen a surge in the incidence of diseases associated with excessive inflammation, including heart disease and type 2 diabetes.

All of which has led to claims that we should not only seek to boost the amount of omega3-s in our diets, but also to cut down on omega-6s. Yet correlation isn't causation. So can it really be that consuming too many omega-6s, long thought beneficial, is bad for us? And if so, what foods should we all be eating more or less of to optimise our omega balance?

Let's start with a few basics. All the fats and oils we eat are composed of fatty acids, which fall into different categories according to their chemical composition. Each affects your physiology in different ways, with knock-on effects for your health. "The quality and type of fat that people eat has a huge impact on age-related diseases, particularly cardiovascular disease," says Philip Calder, a nutritional immunologist at the University of Southampton, UK.

Omega-3 and omega-6 fatty acids are called polyunsaturated fatty acids because they have many double bonds in the long chains of carbon that make up their backbones, whereas saturated fatty acids have none. They are considered "essential" fatty acids, as your body can't make them, meaning you have to get them from the foods you eat. If you didn't, you would get seriously ill – the omega family is known to play a vital role in immunity, brain and heart health and pregnancy (see "Omega-3s in pregnancy", page 42).

The good news is that it isn't difficult to get enough of them in your diet, as long as you eat the right foods. There are three

main types of omega-3s: alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). ALA is found mainly in plants, so good sources include leafy green vegetables, flaxseeds and rapeseed oil. But while our bodies can synthesise DHA and EPA from ALA, they don't do it very efficiently. That is why oily fish such as mackerel, salmon and sardines – all of which contain high levels of DHA and EPA – are considered the most important source of omega-3s.

The main source of omega-6 in our diet is linoleic acid (LA). This is found in seeds, nuts, grains, common vegetable oils such as sunflower oil and cornflower oil, and products made from them, including margarines.

Things get more complicated when we look at what omega fatty acids actually do in our bodies. One of their primary roles is in the cell membrane, where they are integrated into a double layer of fat molecules known as phospholipids. These contain a mix of fatty acids and proteins that control what enters and exits the cell, thus influencing how it behaves.

Importantly, the composition of fatty acids in the cell membrane changes in response to what we eat, with consequences for cell function, says Anthony Hulbert, author of the 2023 book *Omega Balance*. If you have a diet too rich in omega-6 or too deficient in omega-3, he explains, your cell membranes will contain a lot more of the former than the latter. To make matters worse, the enzyme responsible for converting ALA into DHA and EPA can't tell the difference between ALA and LA. This means if your body is awash with omega-6, the two fatty acids compete, resulting in less DHA and EPA.

When that happens, says Hulbert, the result is chronic inflammation, the driving force behind many of the health conditions that are growing ever more common in Western societies today. These include heart diseases, Crohn's disease, type 2 diabetes, rheumatoid arthritis, Alzheimer's, Parkinson's and some cancers. "Omega-6s are important and healthy essential fats," says Hulbert, an emeritus professor at the University of Wollongong, Australia. "But if they are eaten in excessive amounts, omega-6s will diminish the omega-3 content of cell membranes, driving chronic inflammation."

Inflammatory claims

There is a plausible physiological mechanism to connect omega-6s and inflammation. It relates to molecules called eicosanoids, which the immune system uses to convey messages, thereby helping us fight off invaders or heal tissues. Some eicosanoids are made ›

LOWER: SHUTTERSTOCK/XPIXEL; UPPER: GOWITHSTOCK

Foods fried in vegetable oils and sunflower seeds contain high amounts of omega-6 fatty acids

from omega-3s and these tend to be anti-inflammatory. Those made from an omega-6 fatty acid called arachidonic acid (ARA), which is itself synthesised from linoleic acids, are pro-inflammatory.

The idea, then, is that consuming excessive amounts of omega-6 causes cells in the immune system to churn out more pro-inflammatory molecules, causing chronic inflammation.

There is also some evidence for this. For example, studies in humans and other animals show that replacing omega-6s with omega-3s has a positive effect on health, alleviating symptoms associated with chronic conditions like diabetes, heart disease and obesity.

What's more, it is certainly true that the ratio of omega fatty acids we consume in our diets has changed dramatically over the past half-century, with the proportion of omega-6s having risen a great deal.

Hulbert puts these ratios as percentages, where a higher percentage denotes more omega-3 in relation to omega-6. Up until 1910, he says, a typical US diet had an omega balance of around 40 per cent. By 2010, it had dropped to about 9 per cent. The change can be attributed to three things: food manufacturers switching from primarily using animal fats to vegetable oil; farmers feeding their cattle grains rather than grass; and the rise of ultra-processed foods heavy in omega-6s. Over the same period, inflammatory conditions have become increasingly prevalent.

The coincidence is suggestive. However, when it comes to establishing a causal connection between omega-6s and inflammatory conditions, the results from human studies are mixed.

In a 2018 review paper, Calder and Jacqueline Innes, then also at the University of Southampton, UK, concluded that "studies in healthy human adults have found that increased intake of ARA or LA does not increase the concentrations of many inflammatory markers" and that "epidemiological studies have even suggested that ARA and LA may be linked to reduced inflammation".

Calder says that one reason why the results are inconclusive is that our cells already contain such high amounts of ARA that further supplementation is likely to have no effect. "The conundrum is that omega-6s are considered to be harmful, and you can map that out really easily in theory, but when you look at the human data, it doesn't quite pan out like that," he says. "If you give people more LA through supplements, you do not increase ARA in their membranes, but maybe this is because they are already saturated."

The evidence for the beneficial role of omega-3s is much stronger. "What's clear is that if you increase your intake of EPA and DHA and decrease the amount of ARA in your cell membranes, it will reduce inflammation," says Calder.

Omega-3s also seem to be particularly important for brain function. In 2020, for example, Cécilia Samieri at the University of Bordeaux in France and her colleagues published a study in which they followed 10,000 older adults

Omega-3s in pregnancy

Maybe the most compelling evidence that the balance of omega fatty acids in our diets has a big impact on our health (see main story) comes from studies of pregnant women.

In 2020, Robert Gibson at the University of Adelaide in Australia and his colleagues reported a randomised controlled trial in which 5000 women pregnant with a single fetus received either a pill containing 900 milligrams of omega-3 fish oil or a control vegetable oil capsule. The results were clear: if the participants had low levels of omega-3s, they were more at risk of having a preterm birth.

"Not only that, but if those women were given a supplement of omega-3, their risk of preterm births dropped by about 77 per cent," says Gibson.

The reasons why having low omega-3 levels may increase the risk of premature birth aren't known. But Gibson says the women who had a higher risk of preterm birth weren't just deficient in omega-3, they were also high in omega-6. "So there is clearly a balance, and when we correct that and get the balance right, we can overcome the tendency of a mother to give birth prematurely."

This data was used to inform new guidelines issued by the Australian government in 2021. The guidelines state that people who are pregnant should supplement their diet with 800mg of docosahexaenoic acid and 100mg of eicosapentaenoic acid, two types of omega-3 fatty acid, per day, due to their potential to reduce preterm birth.

L: WHITEMAY/GETTY IMAGES R: SHUTTERSTOCK/NATALIAZA

“Wild-caught fish have a better omega balance than farmed fish of the same species”

Leafy greens and oily fish contain high levels of omega-3s

in France over 17 years. They found that people with higher omega-3s showed less cognitive decline and slower brain atrophy – and were less likely to develop dementia. Some scientists believe that omega balance is also linked to depression and other mental health conditions.

There is little doubt that, for most people, getting more omega-3s would be beneficial. But whether we need to increase our intake of omega-3s and cut down on omega-6s, as Hulbert recommends, is up for debate. “There is little evidence for a role of omega-6 on cognitive decline, either positive or negative,” says Samieri. “Some argue that the omega-3/omega-6 ratio is important. However, in practice, in epidemiological research, it is really the level of omega-3 which is important.”

Similarly, Sarah Berry at King’s College London says that as long as you have an adequate amount of omega-3 in your diet, there isn’t much convincing evidence that omega-6 is bad for you. “The omega balance theory is based on the effect that omega fatty acids have on eicosanoids,” she says. “However, the research that has been done in cells and animals to support this theory, in my opinion, does not play out in humans. I would consider omega-6 to be a healthy nutrient, especially for heart health”. For instance, it is one of the best fats at lowering your amount of LDL cholesterol, she says – high levels of which are known to raise your risk of heart disease and stroke.

It could also be that something else is driving the increase in inflammatory conditions. A great deal of omega-6, particularly in the US, is consumed in the form of ultra-processed foods. “There are so many other mechanisms by which these foods may impact our health rather than the omega-6,” says Berry.

For his part, Calder agrees with Hulbert that most people eating a Western diet would benefit from increasing consumption of omega-3s whilst simultaneously eating less omega-6s. “Exchanging one [omega-3] for the other [omega-6] is better than changing just one of them, because you’re changing both sides of the equation,” says Calder.

Optimal balance

The question then becomes what to eat to optimise your ratios. Answering that might seem fraught with difficulty, not least because food labels typically only offer the total polyunsaturated fat content, rather than the relative amounts of omega-3 or omega-6.

But there are a few ways to make a difference. To raise your omega-3 levels, the most important thing is to eat more oily fish. “This is the best way to get more preformed EPA and DHA,” says Calder. If that isn’t possible, there are plant-based alternatives that contain high levels of ALA, which your body will then have to convert to EPA and DHA. Hulbert recommends green leaves, as what little fat they do contain is all ALA. Meanwhile, Calder recommends walnuts, along with flax and chia seeds. “I would also try to reduce omega-6 intake by replacing corn oil, or sunflower oil, with rapeseed oil,” he says.

You do have to be careful, though, because even if you eat foods that are naturally high in omega-3, if they are cooked or stored in omega-6-rich oils, the omega balance will still be low. Hulbert explains that tuna canned in water has an omega balance of 90 per cent, meaning it contains lots of omega-3s and not many omega-6s. When it is canned in sunflower oil, this drops to 16 per cent. Wild-caught fish have a better omega balance, ranging from 63 to 83 per cent, compared with farmed fish of the same species, ranging from 13 to 67 per cent.

If you do eat meat, Hulbert recommends grass-fed beef and lamb, which are good sources of omega-3s. He tends to avoid pork and chicken because they are commonly fed on grain containing soya and corn, which means they are high in omega-6s. He adds that you should also avoid ultra-processed foods, since they are often made with vegetable oils.

As for fish oil supplements, it is vital to check the label to see how much EPA and DHA they actually contain. “If you have a bog-standard fish oil supplement, the amount of EPA or DHA in it is probably around 300 milligrams, whereas if you go home and eat salmon tonight for dinner, it will have around 1.5 grams – over five times as much,” says Calder. However, even low doses of omega-3 over long periods may be beneficial, or at least better than doing nothing at all.

“In the UK, we probably eat about five times more omega-6s than omega-3s, and in the US it is more extreme – probably at least 10 times or more,” says Calder. “If you can redress that balance and up the levels of EPA and DHA in your cell membranes, that is compatible with better health and well-being.” ▮

Jasmin Fox-Skelly is a science journalist based in Cardiff, UK

The back pages

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Mathematics of life

The sum of the square

Pythagoras's theorem is drummed into all of us at school, but **Katie Steckles** was delighted to spot it at work in the wild

Katie Steckles is a mathematician, lecturer, YouTuber and author based in Manchester, UK. She is also puzzle adviser for *New Scientist*'s puzzle column, BrainTwister. Follow her @stecks

Mathematics of life reveals the mathematical ideas and shortcuts behind everyday situations

RECENTLY, I was building a flat-pack wardrobe when I noticed something odd in the instructions. Before you assembled the wardrobe, they said, you needed to measure the height of the ceiling in the room you were going to put it in. If it was less than 244 centimetres high, there was a different set of directions to follow.

These separate instructions asked you to build the wardrobe in a vertical orientation, holding the side panels upright while you attached them to the base. The first set of directions gave you a much easier job, building the wardrobe flat on the floor before lifting it up into place. I was intrigued by the value of 244 cm: this wasn't the same as the height of the wardrobe, or any other dimension on the package, and I briefly wondered where that number had come from. Then I realised: Pythagoras.

The wardrobe was 236 cm high and 60 cm deep. Looking at it side-on, the length of the diagonal line from corner to corner can be calculated using Pythagoras's theorem. The vertical and horizontal sides meet at a right angle, meaning if we square the length of each then add them together, we get the well-known "square of the hypotenuse". Taking the square root of this number gives the length of the diagonal.

In this case, we get a diagonal length a shade under 244 cm. If you wanted to build the wardrobe flat and then stand it up, you would need that full diagonal length to fit between the floor and the ceiling to make sure it wouldn't crash into the ceiling as it swung past – so 244 cm is the safe ceiling height. It is a victory for maths in the real world, and vindication for maths teachers everywhere being asked, "When am I going to use this?"

SHUTTERSTOCK/CLAUDIO GENNARI

This isn't the only way we can connect Pythagoras to daily tasks. If you have ever needed to construct something that is a right angle – like a corner in joinery, or when laying out cones to delineate the boundaries of a sports pitch – you can use the Pythagorean theorem in reverse. This takes advantage of the fact that a right-angled triangle with sides of length 3 and 4 has a hypotenuse of 5 – a so-called 3-4-5 triangle.

If you measure 3 units along one side from the corner, and 4 along the other, and join them with a diagonal, the diagonal's length will be precisely 5 units, if the corner is an exact right angle. Ancient cultures used loops of string with knots spaced 3, 4 and 5 units apart – when held out in a triangle shape, with a knot at each vertex, they would have a right angle at one corner. This technique is still used as a spot check by builders today.

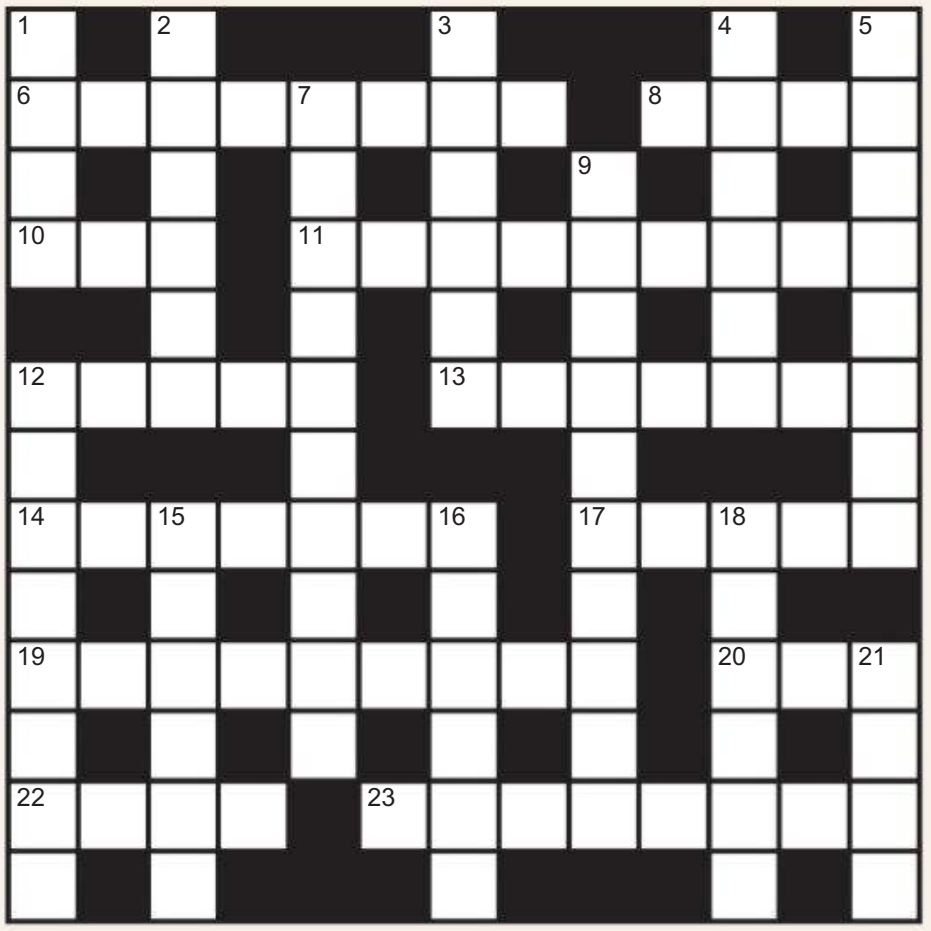
Engineers, artists and scientists might use geometrical thinking all the time, but my satisfaction in building a wardrobe, and finding the maths checked out perfectly, is hard to beat. ▮

These articles are posted each week at newscientist.com/maker

Next week

Debunking gardening myths

Cryptic crossword #134 *Set by Rasa*



Scribble zone

Answers and the next quick crossword next week

ACROSS

6 Go into fancy events backing polysomnogram facility (5,3)
8 Runs across retro British pottery (4)
10 Authored boundless nonsense (3)
11 Resisting reformulation of green pill (9)
12 Soldier pursues recreational mushrooms (5)
13 Beginning to glide into bay beyond river lock (7)
14 Host enters suite where meet-cutes occur (7)
17 Precious northern youngster (5)
19 Steroid tossed to cronies (9)
20 Ester's loving murmur (3)
22 Woodpecker food placed around university (4)
23 Republican bores drink like Hemingway (8)

DOWN

1 Oddly sombre after a tingly sensation (4)
2 On a podcast, tackled elementary particle (6)
3 Band gear inside that woman's carrier (6)
4 Tyre commercial interrupts bad liar (6)
5 Mo's neighbour pitching snug tent (8)
7 Trim superstar and Ian almost seeing the Man in the Moon, say (10)
9 World visionary raised pollution-resistant plants (5,5)
12 Pro manipulated case with time prediction (8)
15 Group of crows on oil barrel looking up (6)
16 Caruso otherwise keeps calm (6)
18 Dutch artist is in Spain with French darling (6)
21 Banded stone coordinates with no counter (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #249
set by Bethan Ackerley

1 Bennet Omalu is best known for his research into which neurodegenerative disease?

2 How many types of B vitamin are there?

3 What was the first non-avian dinosaur to be named?

4 In physics, what does QAHE stand for?

5 In what year was NASA established?

Answers on page 47

BrainTwister
set by Colin Wright (with thanks to Adam Atkinson)
#17 Semi-one numbers

When you count up to 2, exactly half of the numbers contain the digit "1". We can use the term "semi-one numbers" to describe numbers with this property.

The same is true of a number between 15 and 20. Which one?

What is the next semi-one number after that?

Could there be infinitely many such numbers?

Solution next week

Pedal to the metal

We know the maximum possible speed is that of light in a vacuum. But is there a maximum possible acceleration too?

Eric Kvaalen
Les Essarts-le-Roi, France
In general relativity and in quantum mechanics there is no limit to acceleration. But if it turns out that there is a fundamentally shortest length of time, then there would be. In particle physics, decays are usually (if not always) considered to be instantaneous. In any case, if a nucleus emits a beta particle, it ends up going at almost the speed of light, and the decay takes very little time.

John Woodgate
Rayleigh, Essex, UK
Possibly, if Max Planck was right about fundamental minimum limits on measures of distance and time. In which case, the maximum acceleration might be to get to light speed in 1 Planck time, giving 5.559×10^{51} m/s^2.

Ron Dippold
San Diego, California, US
The fundamental limit is that force = mass × acceleration. We

"Most chunks of matter, like us, can only accelerate at a certain rate before the force required gets so big it rips them apart"

can't apply infinite force, so we can't have infinite acceleration. Most chunks of matter, like us, can only accelerate at a certain rate before the force required gets so big it rips them apart. I calculate that a 1 cubic metre block of most types of concrete would collapse at a sustained acceleration of 15,000 m/s^2, for instance.

There is also a quantum phenomenon called the Unruh effect in which acceleration through a vacuum leads to warming by virtual particles. Something accelerating at 10^{26} m/s^2 is expected to face Unruh effect temperatures of 400,000°C! This, too, creates a practical acceleration limit for any molecular object, as it would disintegrate.

What about something like a proton then? The Heisenberg uncertainty principle sets a limit here. It says there is a fundamental restriction on how precisely we can know about pairs of properties of a particle due to quantum effects. Take position and momentum – if you know the position really well, you can't know the momentum well, and vice versa. Energy versus time is the relevant pair here. In 1984, Eduardo R. Caianiello showed that since the energy of a particle at rest is very well known, there is a limit on how fast we can dump more energy into it by accelerating it. In particular, the maximum acceleration is the mass (in kilograms) multiplied by 5.1×10^{59}.

For a proton, which has a rest mass of 1.67×10^{-27} kg, that means a maximum acceleration of 8.6×10^{32} m/s^2 from rest. The Large Hadron Collider takes 20 to 30 minutes to get protons near the speed of light, so is accelerating them at nowhere near this rate.

So yes, there is always an upper limit to the acceleration of anything that depends on the mass and strength of what is being accelerated. For particles, the latter isn't really something we need to worry about, but for larger objects structural strength is an issue.

Mike Follows
Sutton Coldfield, West Midlands, UK
The short answer, at least for photons, is that they don't accelerate. These particles of light are emitted (or launched) at light speed. Of course, this could be perceived as infinite acceleration, which could be explained away by the fact that photons have zero mass (though they do have relativistic mass as a result of movement). But how do we explain why photons appear to slow down or speed up as they move between media with different refractive indices?

Visible light is part of the electromagnetic spectrum. Like all such radiation, one component of light is an alternating electric field. This forces electrons in any atoms it encounters to oscillate up and down in the same way that boats bob up and down on a passing wave. These excited electrons can then reradiate electromagnetic radiation as light, exactly the same as what was absorbed – but there is a slight delay. In effect, photons of light appear to be absorbed in a medium and then re-emitted a little later, so light seems to slow.

The denser the medium, the more often light is delayed, which reduces its average speed and explains why various materials have different refractive indices. It would be like driving on a motorway at the speed limit, but instantaneously stopping for a break at every service station and then instantaneously starting again. Despite travelling at the national speed limit whenever you move, your average speed would be lower.

Materials absorb photons of light when the energy to raise one of the electrons in the constituent atoms to a higher energy state is just right. As a consequence of the Heisenberg uncertainty principle, the smaller the difference between photon energy and this transition energy, the longer energy is "borrowed" by the atom and the more the light is delayed. Blue light is slowed more than red light as it

SHUTTERSTOCK/MURATART

What might we observe from Earth if the already bright star Sirius were to go supernova?

This week's new questions

Twinkle twinkle **What would we see, and how would Earth be affected, if Sirius, the brightest star in our night sky, were to go supernova? Would it be over in a blink or a decade? And would it be visible in daylight?** ***Jan De Wilde****, Ghent, Belgium*

Shower power **Why, when I first step into a hot shower, do I get a brief shiver down my back?** ***Brian Forty****, via email*

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Tom Gauld
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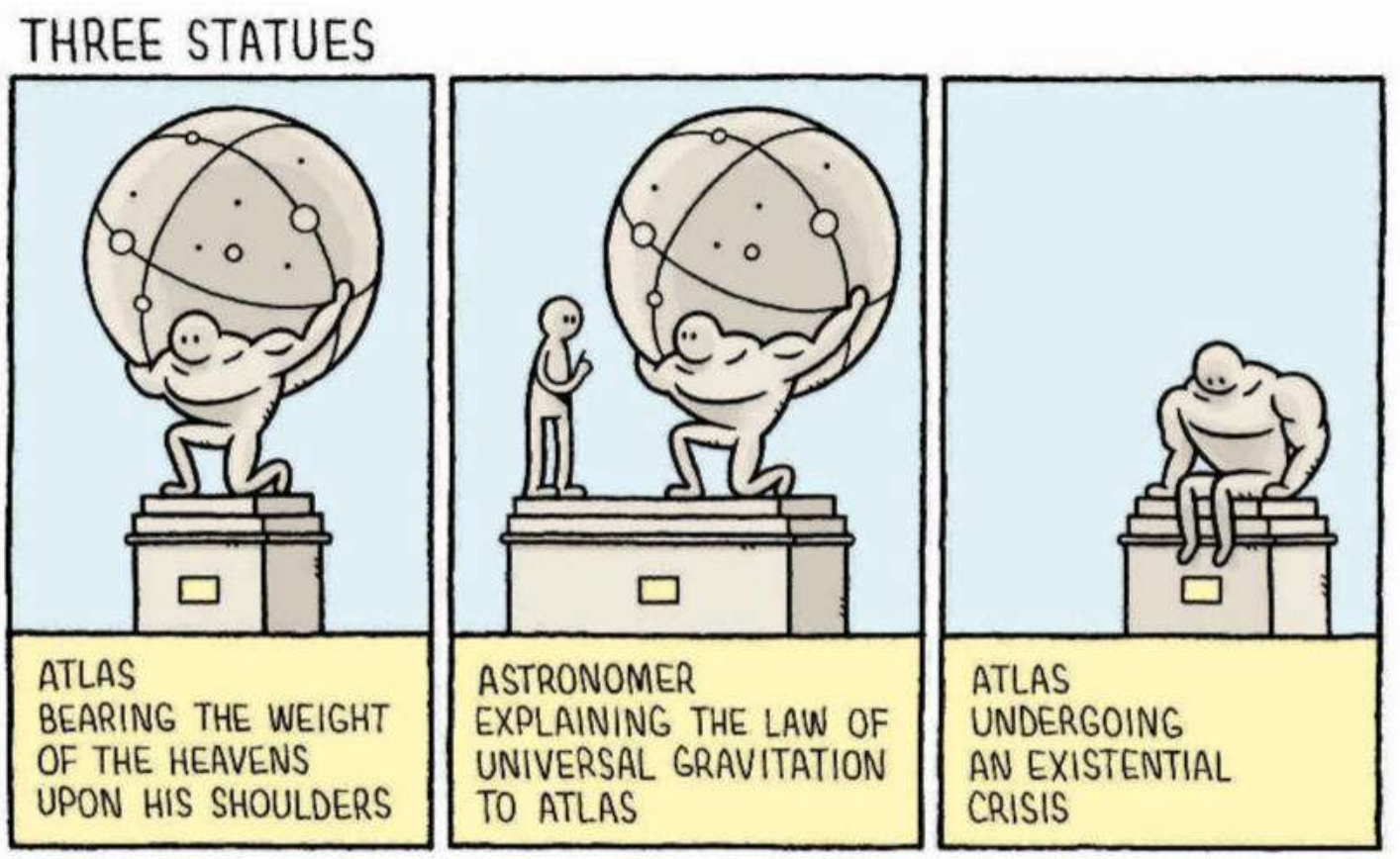

THREE STATUES
ATLAS BEARING THE WEIGHT OF THE HEAVENS UPON HIS SHOULDERS
ASTRONOMER EXPLAINING THE LAW OF UNIVERSAL GRAVITATION TO ATLAS
ATLAS UNDERGOING AN EXISTENTIAL CRISIS

passes through glass because blue is closer to the absorption energy. To extend the motorway analogy, longer rest breaks would mean a lower average speed.

Dog legs

Unlike me, my dogs bound up hills as easily as they run on the flat. Does having four legs aid with climbing, or are the dogs just fitter than me?

Andrew Carothers
Edinburgh, UK

The biologist and evolutionary theorist John Maynard Smith originally qualified and practised as an engineer, giving him unique insights into physical constraints on living organisms. His book, *Mathematical Ideas in Biology*, devotes a section to examining how size affects the ability of animals to move uphill.

By considering the scaling effects of rate of metabolic heat loss, rate of oxygen supply and stresses on bones and muscles, he shows that the maximum power output of an animal should be roughly proportional to the square of its linear dimensions. However, the power needed to move uphill is proportional to the product of weight and vertical velocity. Equating power available to power needed, he concludes that vertical velocity should be inversely proportional to linear dimension. This is borne out by observation: dogs can move uphill with almost as much ease as on the level, whereas climbing quickly exhausts horses and elephants can manage only a slow ascent. Since the number of legs doesn't make any difference, humans must fall somewhere between dog and horse.

"According to Newton's third law, the change in momentum should be shared between me and my dog, but this isn't observed"

So if you are a fit and healthy person being chased by a large hungry bear, you should run up the nearest hill as fast as possible to escape. It isn't a theory that I would care to put to the test myself, as I am over 80, and one factor that Smith didn't take into account was the effect of ageing!

Steven Field
Via email

While dogs' abilities to climb hills may be down to physiology, my experience of walking my 13-year-old collie cross makes me wonder if there are deeper considerations.

When walking on a slack lead, Mutley (at 20 kilograms) can decelerate from fast walking to zero instantaneously. This brings me (at 90 kg) to an immediate stop when the slack vanishes, causing a rebound backwards while the dog remains unmoved. According to Isaac Newton's third law, the change in momentum should be shared by us, but this isn't observed. My hound then appears to become infinitely massive and unmoveable. Perhaps a dollop of dark matter or a canine ability to harness dark energy is at play. Further investigation is required.

Answers

Quick quiz #249 *Answers*

1 Chronic traumatic encephalopathy (CTE)
2 Eight
3 *Megalosaurus*, named 200 years ago in 1824
4 Quantum anomalous Hall effect
5 1958

Quick crossword #156 *Answers*

ACROSS 8 Impetigo, **9** Nausea, **10** Girder, **11** Insomnia, **12** Antimony, **13** Rotate, **14** Cardiopulmonary, **18** Attack, **20** Cuticles, **23** Strobili, **24** Phoebe, **25** Unplug, **26** Nautilus

DOWN 1 Amnion, **2** Headwind, **3** *Vibrio*, **4** Bodily functions, **5** Angstrom, **6** Summit, **7** Resistor, **15** Astatine, **16** Oak Ridge, **17** Necrosis, **19** Apollo, **21** Typhus, **22** Erbium

#16 Order, order! *Solution*

There are many ways to arrange 1–9 so each pair differs by 2 or 3. For example: 1, 3, 5, 2, 4, 7, 9, 6, 8. For pairs to sum to a prime, we must alternate between odd and even numbers (so their sum is odd, since all primes are odd except for 2). We can find valid combinations with a graph in which numbers are connected by a line if they sum to a prime, and any valid route that visits all the numbers will work, such as 1, 2, 3, 4, 7, 6, 5, 8, 9. For adjacent pairs to form values in the times tables, we can determine possible locations for each digit – e.g. nothing in the times tables starts with a 9, so 9 must be at the end, and 6 can only be followed by 3 or 4. Combining these constraints will let us find the solution: 7, 2, 8, 1, 6, 3, 5, 4, 9.

Blood spatter on high

"Be prepared!" This enduring motto of the Scout movement will come to mind for many readers of a paper called "Bloodstain pattern dynamics in microgravity: Observations of a pilot study in the next frontier of forensic science".

Reader Sara Rosenbaum alerted Feedback to the explicitly stated first purpose of the research: "the investigation of eventual violent criminal acts that occur outside of Earth's environment".

This is forensic science at its most future-is-almost-here-istic. And at its most efficiently British-American collaborative-crime-investigation-istic. The researchers are at Staffordshire University and the University of Hull in the UK, and in the US at the University of Louisville in Kentucky and the Roswell Police Department in Georgia.

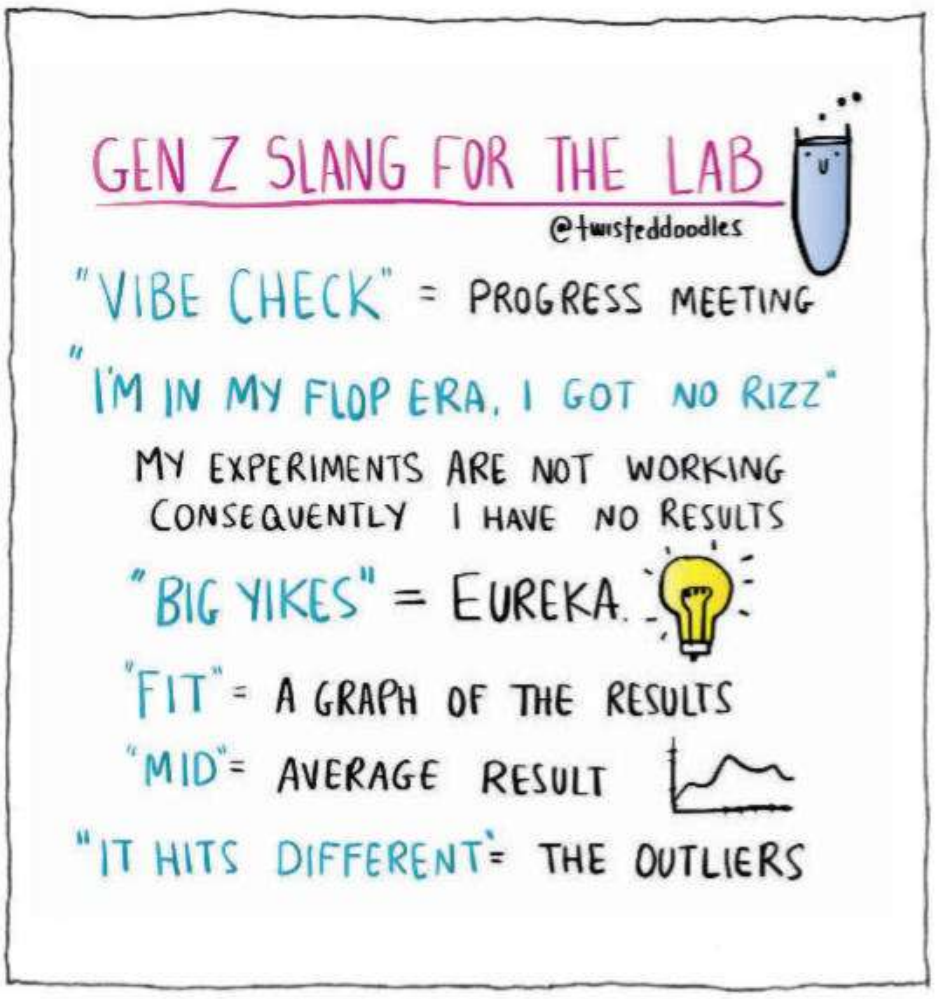
"We hypothesize," they write, "that if gravity is removed as an acting force on a blood drop in flight, then the calculated angle of impact will be more accurate."

They ran, or rather flew, their tests aboard a parabolic flight research aeroplane, departing and landing at the Fort Lauderdale-Hollywood International Airport. (Fort Lauderdale, like many cities in Florida, is accustomed to blood spatter. The city has seen a steadily rising number of violent crimes during the period 2020 to 2023, according to statistics reported by the local police department's Crime Analysis Unit.)

In the experiments, "a 1-cc syringe containing the blood analog was used to project the fluid in a stream on a flight path of approximately 20 cm length that would intercept with a 16.5 cm × 16.5 cm target [made of] 50 lb. paper affixed to a foam board backing".

The study says liquid drops that struck the paper at a 90-degree angle behaved much as the traditional forensic blood-spatter equations predict. But – and this is a challenge to stir the blood of forensic scientists and true-crime aficionados alike – someone needs to come up with better equations for predicting what happens at other angles.

Twisteddoodles *for New Scientist*


GEN Z SLANG FOR THE LAB
@twisteddoodles
"VIBE CHECK" = PROGRESS MEETING
"I'M IN MY FLOP ERA, I GOT NO RIZZ"
MY EXPERIMENTS ARE NOT WORKING
CONSEQUENTLY I HAVE NO RESULTS
"BIG YIKES" = EUREKA.
"FIT" = A GRAPH OF THE RESULTS
"MID" = AVERAGE RESULT
"IT HITS DIFFERENT" = THE OUTLIERS

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Thinking: inside the box

Seeing brings believing, sometimes. Feeling, listening and reasoning – when combined – can be just as powerful.

Sholei Croom, Hanbei Zhou and Chaz Firestone, all at Johns Hopkins University in Baltimore, Maryland, explain in the journal *PNAS* how they tried to answer the question "Can one person tell, just by observing another person's movements, what they are trying to learn?"

They filmed volunteers who "shook an opaque box and attempted to determine i) the number of objects hidden inside, or ii) the shape of the objects inside". They then had other people watch the videos and try to determine "who was shaking for number and who was shaking for shape". Most observers were pretty good at recognising who was shaking for which.

Back in 2017, Myrthe Plaisier at Delft University and Jeroen Smeets at the Vrije Universiteit Amsterdam, both in the Netherlands, told attendees at the IEEE World Haptics Conference in Fürstenfeldbruck, Germany, about a project they called "How Many Objects Are Inside This Box?"

Their method was simple: "we investigated how accurately participants can judge the number of wooden spheres inside a small handheld box by shaking the box". Plaisier and Smeets discovered, they say, that "participants could perform this task accurately for up to about 3 spheres, while for larger numbers they systematically underestimated the numerosity". The larger numbers they tested were four and five. The situation with quantities above that, in theory, remains unknown.

Stick to fruit

Many scientists would be unable to say whether metal sticks to fruit.

It does, generally speaking, if properly coaxed. News of this comes in a study called "Reversibly sticking metals and graphite to hydrogels and tissues" by Wenhao Xu, Faraz Burni and Srinivasa Raghavan, who are all at the University of Maryland.

Writing in the journal *ACS Central Science*, they announce: "We have discovered that hard, electrical conductors (e.g., metals or graphite) can be adhered to soft, aqueous materials (e.g., hydrogels, fruit, or animal tissue) without the use of an adhesive. The adhesion is induced by a low DC electric field... [This] can even be achieved underwater, where typical adhesives cannot be used."

Anticipating a flurry of people aghast at such a simple effect being essentially unknown until now, the study says: "The experiments are very simple."

Accidental genital glow

Faraz Alam sent us a study that he and colleagues at Imperial College London published in 2013 in the journal *PLoS One*, saying: "Here is the paper where I accidentally made genitalia glow in the dark." The title is "Non-invasive monitoring of *Streptococcus pyogenes* vaccine efficacy using biophotonic imaging". Those genitalia were in mice.

That spurred Feedback to recall a paper – about humans – that P. A. Macdonald and M. Sydney Margolese published in 1950 in *Obstetrical & Gynecological Survey*. They called it "Luminescent phenomena of the external female genitalia".

These are examples, both, of how scientists sometimes gain awareness of biological wonders. ∎

Marc Abrahams

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